Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/proceedingsofin701960indi

PROCEEDINGS

of the

Indiana Academy *of* Science

Founded December 29, 1885

•

Volume 70
1960

•

RICHARD A. LAUBENGAYER, Editor
Wabash College
Crawfordsville, Indiana

•

Spring Meeting
May 20-21
Clifty Falls
State Park

Fall Meeting
October 6-8, 1960
Manchester College

Published at Indianapolis, Indiana
1961

1. The permanent address of the Academy is the Indiana State Library.

2. **Instructions for Authors** appear at end of this volume, P.——

3. **Exchanges.** Items sent in exchange for the Proceedings and correspondence concerning exchange arrangements should be addressed:

John Shepard Wright Memorial Library of the Indiana Academy of Science.
c/o Indiana State Library
Indianapolis 4, Indiana.

4. **Proceedings** may be purchased through the State Library at $5.00 per volume.

5. **Reprints of technical papers** can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

6. The Constitution and By-Laws reprinted from v. 62 and the Membership List reprinted from v. 67, are available to members upon application to the Secretary. Necrologies reprinted from the various volumes can be supplied relatives and friends of deceased members by the Secretary.

7. Officers whose names and addresses are not known to correspondents may be addressed care the State Library. The address of the editor of the present volume is Biology Department, Wabash College, Crawfordsville, Ind.

Papers published in the Proceedings of the Indiana Academy of Science are abstracted or indexed in appropriate services listed here:

Annotated Bibliography of Economic Geology

Bibliography of Agriculture

Bibliography of North American Geology

Biological Abstracts

Chemical Abstracts

Chemisches Zentralblatt

Current Geographical Publications

Geological Abstracts

Mathematics Reviews

Metallurgical Abstracts

Psychological Abstracts

Review of Applied Entomology

The Torrey Bulletin

Zoological Record

TABLE OF CONTENTS

Page

Officers and Committees for 1960 6
Minutes of the Spring Meeting 9
Minutes of the Executive Committee 13
Minutes of the General Session 19
New Members of the Year 1960 21
Junior Academy of Science 23
Necrology 31
Presidential Address 41

Anthropology

Abstracts of papers not published in full 46

Bacteriology

Abstracts of papers not published in full 48

Botany

Abstracts of papers not published in full 51
A. G. Kelley and S. N. Postlethwait—Fern Gametophytes as a Tool for the Study of Morphogenesis 56
C. E. Anderson and S. N. Postlethwait—The Organization of the Root Apex of *Glycine max* 61
R. D. Decker and S. N. Postlethwait—The Maturation of the Trifoliate Leaf of *Glycine max* 66
A. E. Brooks—A Preliminary Morphological Study of *Epifagus virginiana* (L.) Bart 73
A. H. Westing—Peroxidase Distribution in Geotropically Stimulated Candles of *Pinus strobus* L 79
Sister Marie Bernard, O. S. F., and M. J. Metzger—Antibiotic Substances from *Ranunculaceae* 83
R. J. Green, Jr. and L. R. Schreiber—Studies of the Control of Oak Wilt Disease in Southern Indiana 87
D. E. Zimmer and J. F. Schafer—Variability of Telial Formation of *Puccinia coronata* 91
Y. Hiratsuka and G. B. Cummins—Morphology of the Spermogonium of *Gymnoconia peckiana*, a Rust Fungus 96

Chemistry

Abstracts of papers not published in full 98
R. E. Davis—Stepwise Construction of Sulfur and Selenium Chains. 100
R. E. Davis—Cyclic Esters of Inorganic Acids I 106
D. J. Cook and R. N. Pierce—Reduction Studies of Various Substituted Carbostyrils 115

Page

H. BURKETT and R. BOWEN—Acid-catalyzed Decarbonylation of 2,4,6-Trimethoxybenzaldehyde. An Anomalous Oxidation Reaction 119
E. E. WEAVER and W. KEIM—A Preliminary of Differential Thermal Analysis, Conductance and Cryoscopic Behavior of Dimethyl Sulfoxide Complexes 123
J. A. RICKETTS and L. D. NICHOLS—Some One Dimensional Atomic Potential Functions 132

Entomology

Abstracts of papers not published in full 137
G. L. WARD and C. COLE—Quantitative Comparison of Insect Orders from Three Types of Vegetational Cover on Miami, Bethel and Brookston Soils in Eastern Indiana 139
G. L. WARD and T. G. MARSH—Diptera Populations in the Whitewater Valley 142
J. V. OSMUN—Insects and Other Arthropods of Economic Importance in Indiana in 1960 145
R. C. DOBSON and D. L. MATTHEW—Field Observations of Face Fly (*Musca autumnalis* DeGeer) in Indiana, 1960 152

Geology and Geography

Abstract of paper not published in full 154
R. H. L. HOWE—Discovery and Evaluation of Water Resources by Aerial Photographic Method 155
L. GUERNSEY—Settlement Changes Caused by Strip Coal Mining in Indiana 158
M. C. BOYER—Geomorphology and Floods 165
T. F. BARTON—The Monroe Reservoir: A Multiple Use Project 170

History of Science

W. E. EDINGTON—Biographical Sketches of Indiana Scientists Not Listed Elsewhere, I 182
S. S. VISHER—Progress Made in Increasing Indiana's Human Resources 189
F. K. DAILY—The Academy from Horse and Buggy to Jet 194

Mathematics

Abstracts of papers not published in full 200

Physics

Abstracts of papers not published in full 203

Plant Taxonomy

Abstracts of papers not published in full 207

Page
C. B. HEISER, JR.—A New Annual Sunflower, *Helianthus deserticolus*, from Southwestern United States 209
W. A. DAILY—Forms of *Ceratium hirundinella* (O. F. Müller) Schrank in Lakes and Ponds of Indiana 213

Psychology

No meeting reported.

Soil Science

Abstracts of papers not published in full 216
R. K. STIVERS, D. WIERSMA and J. G. FLORES—Evaluation of Three Sources of Nitrogen for Corn 217
S. D. EVANS and S. A. BARBER—The Effect of Soil Depth and Soil Volume Upon Corn Yield in a Greenhouse Experiment 227
F. B. CLARK—Pot Culture—An Aid to Site Evaluation 234
T. LAVY, G. SANDS and S. BARBER—The Molybdenum Status of Some Indiana Soils 238
G. E. WILCOX—Potato Nutrition in Southwestern Indiana 243
A. F. GOHLKE and M. F. BAUMGARDNER—Statistical Evaluation of the Analytical Techniques Employed in the Purdue Soil Analysis Laboratory 248
B. T. KANG and A. J. OHLROGGE—The Response of Corn Roots to High Nutrient Concentrations within a Single Root Culture Cell 254

Zoology

Abstracts of papers not published in full 260
J. B. COPE, W. BAKER and J. CONFER—Breeding Colonies of Four Species of Bats of Indiana 262
J. B. COPE, E. CHURCHWELL and K. KOONTZ—A Method of Tagging Bats with Radioactive Gold-198 in Homing Experiments 267
J. B. COPE, K. KOONTZ and E. CHURCHWELL—Notes on Homing of Two Species of Bats, *Myotis lucifugus* and *Eptesicus fuscus* 270
R. E. MUMFORD and R. D. KIRKPATRICK—Distribution of the 13-lined Ground Squirrel in Indiana 275
A. E. REYNOLDS—A Postfemoral Spot in *Plethodon* 278
W. C. GUNTHER, R. K. JONES and P. MANSKE—Some Effects of High and Low Incubating Temperatures on Chick Behavior 285

Appendix

Instructions for Contributors 293
Index to Volume 70 295

Officers and Committees of the Indiana Academy of Science for 1960

Spring Meeting: May 20-21, Clifty Falls State Park, Madison, Indiana.
Fall Meeting: October 6, 7, 8, Manchester College, North Manchester, Indiana

OFFICERS FOR 1960

President.....A. T. Guard, Purdue University
Vice President.....Lawrence H. Baldinger, Notre Dame University
Secretary.....William W. Bloom, Valparaiso University
Treasurer.....Donald J. Cook, DePauw University
Editor.....R. A. Laubengayer, Wabash College
Press Secretary .....Eugene Weinberg, Indiana University

CHAIRMEN ELECTED BY THE DIVISIONS

Anthropology.....M. S. Wadia, Indiana University
Bacteriology.....W. A. Zygmunt, Mead Johnson and Company
Botany.....S. N. Postlethwait, Purdue University
Chemistry.....H. B. Burkett, DePauw University
Entomology.....R. E. Niswander, Manchester College
Geology and Geography.....J. C. Hook, Indiana State Teachers College
History of Science.....Fay K. Daily, Butler University
Mathematics.....Kermit H. Carlson, Valparaiso University
Physics.....C. S. Morris, Manchester College
Plant Taxonomy.....W. A. Daily, Eli Lilly & Company
Psychology.....D. C. Colburn, Manchester College
Soil Science.....Stanley A. Barber, Purdue University
Zoology.....Carl H. Krekeler, Valparaiso University

EXECUTIVE COMMITTEE

(Consisting of Past Presidents, Current Officers, Divisional Chairmen, and Chairmen of Standing Committees)

L. H. Baldinger
S. A. Barber
W. W. Bloom
H. B. Burkett
K. H. Carlson
O. B. Christy
R. E. Cleland
N. M. Coats
D. C. Colburn
D. J. Cook
F. K. Daily
W. A. Daily
J. J. Davis
E. F. Degering
L. E. DeLanney
W. E. Edington
P. D. Edwards
A. T. Guard
M. T. Hall
J. C. Hook
W. H. Johnson
T. K. Just
P. Klinge
K. H. Krekeler
R. A. Laubengayer
R. W. Lefler
S. McCoy
C. A. Markle
M. S. Markle
M. G. Mellon
A. H. Meyer
H. H. Michaud
W. P. Morgan
C. S. Morris
R. E. Niswander
J. C. Polley
C. L. Porter
S. N. Postlethwait
H. M. Powell
W. J. Rice
S. S. Visher
M. S. Wadia
F. N. Wallace
P. Weatherwax
E. D. Weinberg
Winona H. Welch
T. G. Yuncker
W. A. Zygmunt

BUDGET COMMITTEE

Consisting of President, Secretary, Treasurer, Editor, Chairman of the Junior Academy, Library, Program, and Relation of Academy to State: A. T. Guard, W. W. Bloom, D. J. Cook, R. A. Laubengayer, H. H. Michaud, Nelle M. Coats, Wm. Eberly, Wm. Daily, F. N. Wallace.

COMMITTEES ELECTED BY THE ACADEMY

Trustees of the Academy Foundation (term 4 years): Chairman, Ward J. Rice (term expires 1960), J. E. Seybert (term expires 1961).

Bonding of Trustees (elected annually): Chairman, Scott McCoy, Technical H. S., Indianapolis; F. J. Welcher, Indiana University, Adult Education Center, Indianapolis.

Research Grants (term 5 years): Chairman, T. G. Yuncker, DePauw University (term expires 1964); Keith M. Seymour (term expires 1965); Paul Weatherwax (term expires 1961); A. A. Lindsey (term expires 1963); J. F. Hart (term expires 1962); A. T. Guard and William W. Bloom (ex officio).

COMMITTEES APPOINTED BY THE PRESIDENT

Auditing: Chairman, W. P. Morgan, Ind. Central College; F. J. Welcher.

Biological Survey: Chairman, C. A. Markle, Earlham College; Fay K. Daily; D. G. Grey; C. J. Goodnight; H. H. Michaud; W. H. Welch; F. N. Young, Jr.; J. Webster.

Fellows Committee: Chairman, P. D. Edwards, Mathematics, Ball State Teachers College; H. H. Remmers, Psychology; H. Driver, Anthropology; Winona H. Welch, Botany; L. S. McClung, Bacteriology; K. Seymour, Chemistry; H. O. Deay, Entomology; T. F. Barton, Geology and Geography; M. S. Markle, History of Science; A. C. Mitchell, Physics; A. R. Bertrand, Soil Science; N. Pearson, Zoology.

Index: Chairman, R. A. Laubengayer, Wabash College; Nelle Coats; Mrs. L. Burton.

Indiana Talent Search: Chairman, R. L. Lefler, Purdue University; R. S. Shulz; L. H. Baldinger; P. D. Edwards; C. A. Markle; M. Correll; Sears Crowell.

Invitations: Chairman, Marion T. Hall, Butler University; A. H. Meyer.

Junior Academy: Chairman, H. H. Michaud, Purdue University; R. Cooper; P. E. Klinge; Lola Lemon; R. E. Niswander; R. W. Schulz; J. Cope; D. Webster; R. Weber.

Library: Chairman, Nelle Coats, State Library; Eli Lilly, G. A. Black.

Membership: Chairman, Louis E. DeLanney, Wabash College; John A. Buehler, Anderson College; H. M. Dixon, Butler University; M. R. Garner, Earlham College; E. Niswander, Manchester College; J. Webster, Hanover College; J. F. Hennen, State Teachers College; Jerry J. Nisbet, Ball State Teachers College; Lois Farquharson, Franklin College; G. F. Hennion, University of Notre Dame; R. G. Larson, Valparaiso University; G. R. Miller, Goshen College; F. J. Zeller, Indiana University.

Necrologist: W. E. Edington, DePauw University.

Program: Chairman, W. R. Eberly, Manchester College; H. Weimer; C. Morris; J. Baumgart; E. Niswander; P. Orpurt; W. Bessey; G. Wickwire:

Publication of Proceedings: Chairman, R. A. Laubengayer, Wabash College; A. A. Lindsey; James Clark.

Publicity: Chairman, Eugene Weinberg, Indiana University; Nelle Coats; H. Weimer; R. Nelson.

Relation of Academy to State: Co-chairmen, F. N. Wallace, Dept. of Conservation, and W. A. Daily, Eli Lilly Co.; J. A. Clark; Eli Lilly; H. J. Reed; R. A. Laubengayer.

Representative on Council of the AAAS: C. B. Heiser, Indiana University.

Resolutions: Chairman, Winona H. Welch, DePauw University; S. D. Gerking; E. L. Haenisch.

Science Education: Chairman, Paul Klinge, Indiana University; K. Dale; R. Lefler; W. Smith; R. S. Shulz; H. N. Hardy (University School, Bloomington); L. Poorman (Columbus High School).

Indiana High School and College Committee on Mathematics: Chairman, J. C. Polley, Wabash College; G. N. Wollan; G. Vannatta.

SPRING MEETING
EXECUTIVE COMMITTEE

Clifty Falls State Park
May 20, 1960
4:30 P. M.

The meeting was called to order by the president, Dr. A. T. Guard.

Editor Richard Laubengayer was unable to be present but submitted a written report. He reported that there had been some slowness in getting the galley proofs so that they would not go out to contributors until the second week in June. The need of contributors getting their material to the editor was noted and members were urged to observe the published deadline for submitting papers for publication.

Nelle Coats, librarian, reported that the library still had many copies of the Index for Volumes 1-50 and that new members may need copies. Extra copies of volumes 51-61 of the proceedings were also available. About 500 copies of Indiana Scientists are available at $2.50. Volume 67 is exhausted and copies of this volume would be welcomed by the librarian. She reported that Mrs. Wright had given $500.00 to the library and suggested the purchase of an herbal.

The program chairman, William Eberly, reported on plans for the fall meeting at Manchester College. Following a discussion of the need for projection equipment it was moved and carried that the program chairman request the divisional chairmen to try to provide projection equipment.

The treasurer, Donald J. Cook, submitted the following tentative financial report as of April 30, 1960:

Receipts:		
Bank Balance as of Jan. 1, 1960	$21,324.65	
Total Receipts thru April 30, 1960	1,381.30	$22,705.95
Disbursements:		
Total Disbursements thru April, 1960		$ 8,316.47
Balance on Hand May 1, 1960		$14,389.48
Account Balances on Hand, May 1, 1960		
John Shephard Wright Library Account	$ 1,727.73	
Indiana Science Talent Search Account	181.43	
N. S. F. Visiting Scientists Account	9,263.59	
Indiana Academy of Science Funds	3,216.73	
		$14,389.48

A motion carried that the treasurer transfer $898.95 from the Academy funds to the Lilly Endowment Fund Gift.

The treasurer called attention to the increasing work load placed upon his office by the increasing activity in the visiting scientist and mathematician programs. Doctors Guard, Cook, Michaud, and someone from the mathematics program are to meet and work out a solution to reduce the load on the treasurer's office.

Mr. Paul Klinge reported for the Press Secretary, Eugene Weinberg, in his absence and emphasized the need for adequate abstracts to papers

so that news stories can be written. He suggested that the News Bureaus of the local institutions be utilized to help in preparing newsworthy abstracts.

The Science Education Committee chairman, Mr. Paul Klinge, presented extensive recommendations to the Executive Board concerning the youth programs of the Academy.

Following are the recommendations to the Executive Board:

At a meeting of the Education Committee Saturday, February 20, 1960, at the Indiana University Medical Center, the members of this committee were unanimous in the following recommendations to the Executive Board for the reorganization of the youth activities of the Academy.

The youth programs of the Academy at present constitute the State Science Fairs, the Indiana Science Talent Search, the Junior Academy of Science, and the Visiting Scientist Lectureship Program.

We recommend the following:

All the youth programs of the Indiana Academy of Science should be put under the supervision of an Administrative Committee. In addition, members of the Education Committee may be considered as candidates for the Administrative Committee. The function of the Administrative Committee would be to set up rules and regulations for these programs, exercise appointive power in the direction of the programs, and have authority to formulate policy for the conduct of each one of the current youth programs.

In addition, a Finance Committee should be set up under the chairmanship of a member of the Academy, and other members of this Committee will include outstanding industrial, commercial, and business leaders of this state as well as ex officio members from the Administrative Committee. The chief purpose of this Committee will be to raise funds which will be necessary to carry on the programs in a more financially comfortable arrangement. The current budget of some $10,000 for these programs should be increased to a possible $15,000 for the programs to run more smoothly. Some of this money will be necessary for the administration of these programs as this has been assumed in the past to a large degree by state colleges and universities.

It is further recommended that these programs be confined to two times during the academic year. At present, it is hoped that the fall program will be largely under the control of the Junior Academy of Science. The general arrangement of this program will be to encourage students to read papers of their science work. It seems necessary now to make some selection of the papers which will be read at this meeting. It is hoped that the fall meeting will be one of motivating students to further work in science as well as to give an opportunity for students to read papers of their work before an audience.

The spring event should be the concluding meeting of the other programs in the current youth program of the Academy. This may tentatively be called a Science Congress. This will include a display of the projects of students who have placed in the Indiana Science Talent Search as well as those students who have been chosen from Regional Science Fairs throughout the state. This will be a culminating event for gifted high school science students in their work in the preceding academic year.

The tentative reorganization plan of the Science Fairs of the state is as follows: Colleges and universities in the state will be permitted to organize their own local Science Fairs with students having the option of which of these Science Fairs they wish to enter. The best projects from each of these university and college Science Fairs will be chosen on an area basis, perhaps four such areas in the state. These projects will then be displayed at the Science Congress in the spring. Winners from the Science Congress Science Fair exhibits will be candidates for attending the National Science Fair. Winners from local Science Fairs, sponsored by universities and colleges, will also have the option of attending the National Science Fairs under financial arrangements which local institutions may devise.

The narrative account of the meeting of the Education Committee in February has been submitted to Professor Guard, and it includes details of the discussion of which the above recommendations were the result. It should be indicated that Professor Lefler feels that he should relinquish the leadership of the Science Talent Search and the Science Fairs, and the proposed Administrative Committee, mentioned above, should appoint new directors of these activities. However, it was the feeling of the Committee that Professor Lefler should still remain on the Administrative Committee.

It is the feeling of the Education Committee that this reorganization will permit high school science teachers to be less confused about all of the activities now in operation for science student activities. Publicity and definite financial arrangements would be more easy to obtain with this proposed reorganization, the Committee felt.

We recommend to the Executive Board of the Indiana Academy of Science the adoption of the above recommendation.

MRS. CATHERINE DALE, Griffith, Chemistry Teacher
PROFESSOR RALPH LEFLER, Purdue University
MR. LAWRENCE POORMAN, Columbus High School, Physics Teacher
PROFESSOR RICHARD SCHULZ, Purdue University
MR. WILLIAM SMITH, Howe High School, Biology
PROFESSOR PAUL KLINGE, Indiana University, Chairman

Other persons present:

PROFESSOR A. T. GUARD, Purdue University
President, Indiana Academy of Science
PROFESSOR HOWARD MICHAUD, Purdue University,
Director, Junior Academy of Science
MR. EBNEST LITWEILER, John Adams High School, South Bend,
Member of Junior Academy of Science Board

April 14, 1960

A motion carried to accept the recommendations of the committee and instructing the president to appoint the two committees included in the recommendations.

WILLIAM W. BLOOM, *Secretary*

Approved 10-7-60

SPRING MEETING

DINNER MEETING

CLIFTY FALLS STATE PARK

May 20, 1960

Dr. A. T. Guard called the meeting to order and extended words of welcome to the members. The officers of the Academy present were introduced by the President.

Eighteen new members were accepted into the Academy and three new Junior Academy clubs were received.

Dr. William Eberly, program chairman, reported that sixty participants had registered and were staying over in the Inn and announced the field trips for Saturday morning.

Dr. Markle, as speaker for the evening, gave a most interesting account of his recent visit to Hawaii and used his excellent color slides to illustrate his talk on the people and the flora of the islands.

Following the adjournment of the meeting, Mr. Gerken, manager of Clifty Inn, served refreshments for the members of the Academy.

WILLIAM W. BLOOM, Secretary

Approved 10-7-60

FALL MEETING

EXECUTIVE COMMITTEE

MANCHESTER COLLEGE, North Manchester, Ind.

The meeting was called to order by President A. T. Guard at 7:35 P. M.

The minutes of the spring meeting of the Executive Committee of the Academy and the minutes of the dinner meeting held at Clifty Inn at Clifty Falls State Park were read by the secretary and approved as read.

Reports of officers and chairmen of committees:

Treasurer—Donald J. Cook: Financial report of the Indiana Academy of Science, Jan. 1, 1960 thru Dec. 31, 1960.

FINANCIAL REPORT OF THE INDIANA ACADEMY OF SCIENCE AS OF DECEMBER 31, 1960

Receipts

Balance on Hand—January 1, 1960	$21,324.65	
Dues and Initiation Fees	3,151.00	
Sales and Reprints: Vol. 68	636.28	
Sale of Publications	18.50	
Refunds	19.69	
Indana Science Talent Search	1,275.00	
Endowment Funds for Research Grants	300.00	
National Science Foundation Grant No. G-12417	17,150.00	
National Science Foundation Grant No. G-12412	13,710.00	
TOTAL RECEIPTS	$57,585.12	$57,585.12

Disbursements

Editor—Vol. 69 of Academy Proceedings	$ 225.00
National Science Fair	100.00
Indiana Science Talent Search: IAS Funds	200.00
Indiana Science Talent Search	1,774.13
Academy Conference	12.34
Expenses of Treasurer	130.00
Expenses of Secretary	90.65
Expenses of Program Committee	321.75
Stationery	147.50
John S. Wright Library Fund	200.00
Binding of Periodicals from Academy Funds	997.65
Cost of Publishing Vol. 69 of Proceedings (In Excess of State Payment)	1,636.23
Cost of Reprints for Vol. 69	994.43
Expenses of Indiana Jr. Academy of Science	55.93
Expenses of Academy Officers	125.00
Grants-In-Aid for Research: Fay Daily	100.00
Charles Hall	100.00
Misc.: Postage, Office Supplies, etc.	108.81
National Science Foundation Grant G-8724	9,195.90
National Science Foundation Grant G-12412	13,710.00
National Science Foundation Grant G-12417	2,686.35
Transfer of Funds to Treasurer-Elect Kermit Carlson from NSF G-12417 monies	5,000.00

Refund to National Science Foundation of Unexpended Balance of Grant No. G-8724	5,829.42	
TOTAL DISBURSEMENTS	$43,741.09	$43,741.09
BALANCE ON HAND AS OF DECEMBER 31, 1960		$13,844.03
BALANCE ON HAND in the Following Accounts as of 12-31-60 :		
John S. Wright Library Fund	$ 2,426.68	
Indiana Science Talent Search	639.09	
Visiting Scientists NSF Grant G-12417	9,463.65	
Academy Funds (Of which $400. is designated for Research)	1,314.61	
	$13,844.03	

Editor—Richard A. Laubengayer: There were 1,292 hardbound and 610 softbound copies of Volume 69 of the *Proceedings* which had been printed, giving a total of 1,902 copies. These have been distributed by the State Library. Forty-one of the contributors ordered reprints.

Press Secretary—Eugene D. Weinberg: Notices of the 76th Annual Meeting of the Academy had been issued to each of the State's daily newspapers and to the wire services. In addition releases have been issued concerning the general meeting, the meetings of the Divisions, the banquet, and the Junior Academy. Subsequent releases will be issued concerning the election of officers of the Academy and of the Junior Academy and the winners of the awards in the Junior Academy. A request was made that contributors of papers to the sessions submit newsworthy popular abstracts of their papers to the Division Chairmen well in advance of the meetings so that adequate news coverage of the scientific papers presented can be secured in advance of the meetings.

Nominations Committee—Willis H. Johnson, chairman of the committee: Nominated as Trustees of the Academy Foundation: Chairmen, Ward J. Rice and William A. Daily to complete the term of J. E. Sybert. Scott McCoy and Frank Welcher were nominated to succeed themselves as members of the Bonding of Trustees Committee.

Fellows Committee—P. D. Edwards: The following members were recommended for fellows in the Indiana Academy of Sciences: Lawrence Manning Baker, Psychology, Purdue University; James Edward Canright, Botany, Indiana University; Paul Henry Gebhard, Anthropology, Indiana University; Edward W. Shrigley, Michobiology, Indiana University Medical Center; Joe Lloyd White, Agronomy, Purdue University; James Thorp, Geology, Earlham College.

Biological Survey Committee—Submitted by the chairman, Carroll A. Markle, and presented by Winona H. Welch:

Report of the Biological Survey Committee of the Indiana Academy of Science

Publications of 1959-1960 Dealing with the Flora and Fauna of Indiana

Algae:

1. Palmer, C. Mervin and Earle Brown, 1960. Pectodictyon and other Unusual Algae from Indiana. Proceedings of the Indiana Academy of Science for 1959, **69**: 119-122.
2. Thomas, Clarence, 1960. Some Algae of the St. Meinrad Area. Proceedings of the Indiana Academy of Science for 1959, **69**: 121-133.

Bryophyta : Welch, Winona H., 1960. Studies in Indiana Bryophytes XII Proceedings of the Indiana Academy of Science for 1959, **69** : 123-127.

Vascular Plants :
1. Markle, Carrolle A., 1960. Contributions to the Flora of Wayne County, IV. Proceedings of the Indiana Academy of Science for 1959, **69** : 266-268.
2. McCoy, Scott, 1960. New County Records for Indiana (Abstract). Proceedings of the Indiana Academy of Science for 1959, **69** : 262.

Annelida : Joyner, James W., 1959. Earthworms of the Upper Whitewater Valley (East Central Indiana). Proceedings of the Indiana Academy of Science for 1959, **69** : 313-319.

Crustacea : Eberly, William R., 1960. Competition and Evolution in Cave Crayfish of Southern Indiana. Systematic Zoology, 9(1) : 29-32. March 1960.

Insecta :
1. Matthew, D. L. and R. C. Dobson, 1960. *Musca autumnalis* (DeGeer), a New Livestock Pest in Indiana. Proceedings of the Indiana Academy of Science for 1959, **69** : 165-166.
2. Osmun, John V., 1960. Insects and Other Arthropod of Economic Importance in Indiana in 1959. Proceedings of the Indiana Academy of Science for 1959, **69** : 167-177.
3. Schuder, Donald L., 1960. *Tortrix pallorana* Rob., A Pest of Pine Trees in Indiana. Proceedings of the Indiana Academy of Science for 1959, **69** : 175-177.
4. Young, Frank N., 1960. The Water Beetles of a Temporary Pond in Southern Indiana. Proceedings of the Indiana Academy of Science for 1959, **69** : 154-164.

Pisces : Dineen, Clarence F., 1960. Semi-Annual Report for Stream Investigations Bottom Types and Bottom Organisms of the Saint Joseph Drainge In Indiana. Indiana Department of Conservation Fisheries Research Report., Vol. 3, No. 2, pp. 2-26.

Work in Progress or Completed in 1959-1960 But Not Yet Published

Algae :
1. Daily, F. K. Some Fossil Charophyta from North America (Chiefly Pleistocene).
2. Daily, W. A. Forms of Ceratium hirundinella (O. F. M.) Schrank in Lakes of Indiana.
3. Hall, Charles R. Algae of Putnam County, Indiana.

Vascular Plants :
1. Bloom, William W. Guide to the Common Ferns of Indiana (Illustrated).
2. Clewell, Andre. Variation in *Lespedeza hirta* and Relatives.
3. Hall, Gustav. *Bidens* in eastern North America.
4. Heiser, C. B. Jr. *Gleditsia triacanthos, G. aquatica* and their Hybrid in Indiana.
5. Lindsey, Alton A., Robert O. Petty, David K. Sterling and Willard Van Asdall. Vegetation and Environment along the Wabash and Tippecanoe Rivers. Ecological Monographs.
6. Purelis, Gina. Varation in *Aster lateriflorus* in southern Indiana.

Insecta :
1. Krekeler, Carl H., Anophthalmids of Indiana (Cavernicolous Carabidae).
2. Siverly, R. E., Distribution and Ecology of Mosquitoes of Indiana ; Insect Rearing.
3. Ward, Gertude L., Insects of Eastern Indiana.

Amphibia :
1. Randall, E. J., Studies on Reproductive Potentials of Ambystomid Salamanders.

	2.	Gordon, R. E. and K. S. Tweedell, Radiation Effects on Hybrid Salamanders (Ambystomidae).
Aves:		Cope, James B. Birds of Indiana
Mammalia:		Cope, James B. Bats of Indiana.
Miscellaneous Plant and Animal Groups:	1.	Laubengayer, Richard A., Inventory of Plant and Animal Groups in Allee Memorial Woods, Parke County, Indiana.
	2.	Williams, Eliot C., Jr., Quantitative and Population Studies of Certain Insect, Reptile, Mammal and other Faunal Groups in the Allee Memorial Woods, Parke County, Indiana.

Library Committee—Nelle Coats: A report was submitted for the John Shepard Wright Memorial Library. As superior display material there was purchased, as part of Mrs. Wright's $500.00 gift, a fine copy of W. P. C. Barton's "A Flora of North America, Illustrated by Coloured Figures Drawn from Nature," a three volume work published in Philadelphia 1821-23. With its 106 color plates, it is a first edition of the finest early American herbal. Another medical botany suitable for exhibit was presented by Mr. Eli Lilly, "The Badianus Manuscript, an Aztec Herbal 1552." Published by Johns Hopkins Press in 1940, the volume is now out of print and scarce.

Volume 69, the *Proceedings* for 1959, was published September 8, 1960 and as usual the Indiana State Library supplied envelopes and labor for distributing copies to members.

Mrs. Lois Burton has prepared and sent to the bindery 224 volumes from the Academy Library, estimated cost to be $997.65, approximating the sum allotted by the Budget Committee.

The Taxonomic Index is added to indexing or abstracting services covering the *Proceedings* bringing the total to 15.

A new edition of the great "Union List of Serials in the U. S. and Canadian Libraries" is in preparation and the necessary checking for inclusion of the Wright Library holdings is being done. This year 21 new titles have been added to those currently received.

An exhibit of some of the materials was prepared for the 1959 meeting and, as this was a 75th anniversary for the Academy, photographs and articles illustrating its history were also shown. Another exhibit was prepared for the Indiana Science Talent Search Assembly in the spring.

Invitations Committee—Marion T. Hall: The Indiana State Teachers College, Terre Haute, Indiana, has invited the Academy to hold its fall meeting in 1961 on their campus. The meeting dates are to be October 19, 20, and 21. The recommendations of the committee were accepted.

Program Committee—William Eberly: The chairman expressed his appreciation of the work of the members of the Academy associated with him in preparing the program and getting things in readiness for a meeting this early in the academic year. He noted that room 104 in the new Hall of Science had been set aside for Academy headquarters.

Research Grants—T. G. Yuncker: Attention was called to the fact that some Academy monies are available to members for research yet this year. Applications should be made to the chairman.

Relation of Academy to State—W. A. Daily and F. N. Wallace: Mr. Daily reported that a budget request for legislative appropriation has

been submitted to the State Budget Committee for the sum of $4,000 per annum for the fiscal years 1961-1962 and 1962-1963. The report was accepted.

Junior Academy—Howard H. Michaud: There was a registration of 437 students, teacher club sponsors, and guests for the 1959 meeting of the Junior Academy. Eighteen exhibits and seventeen papers were presented. William D. Schall of Central Junior-Senior High School, South Bend, received the "best boy" award and Patricia Coleman, Washington High School, Indianapolis, received the "best girl" award. Garfield High School of Terre Haute and Washington Catholic High School, Washington, received the Kroger Awards for showing evidence of the best high school science programs based on a self-evaluation questionnaire sent to Indiana high schools. Marilyn Wickman of Washington Catholic High School, Washington, and Norman Pace of Edinburg High School received the Society of American Bacteriologists awards in bacteriology. The twenty-eighth annual meeting of the Junior Academy will convene October 8th at Manchester College.

Visiting Scientists—Dr. Michaud also reported on the Visiting Scientists Program for Indiana High Schools made possible by a grant from the National Science Foundation. The total amount of the grant was $16,750. This program provided for 250 visits by Indiana College Scientists and Mathematicians to Indiana High Schools as well as $2,500 for the purchase of expendable materials by high school students for individual research projects. A total of 88 scientists representing 19 of the state's 31 colleges were listed as participants, brochures were sent out to all private and public high schools, and about 200 requests were received. One hundred seventy-seven visits were completed. Two major objectives of the program were (a) to develop better understanding and cooperation between college scientists and the secondary schools, and (b) to encourage more college scientists to assume an active interest in the improvement of the high school science program. Both of these objectives, it is certain from reports received, were exceptionally well met. A similar grant in the amount of $17,150 has been approved by the N. S. F. for 1960-61 academic school year. An application to continue the program for the 1961-62 school year has been made. Dr. Donald J. Cook, as treasurer of the Indiana Academy of Science, is fiscal agent for the N. S. F. funds.

Indiana School and College Committee on Mathematics—J. C. Polley: A report on the activities of the committee during the 1959-60 academic year was given. The committee has been working to develop a program of activities designed to involve mathematics teachers at all levels in an effort to improve the mathematics program. The committee has promoted local meetings designed to bring college and school mathematics teachers together to discuss their programs. Meetings have been sponsored by colleges or local councils of mathematics teachers. Last year eight such meetings were held and this year 12 are planned. About 200 school administrators and mathematics teachers attended a conference at Indiana University to discuss the experience of Indiana schools with experimental programs. Four or five similar conferences are planned for this year as well as a conference at Purdue University to discuss training of school mathematics teachers.

Indiana Science Talent Search—Ralph Lefler: A report was given on the thirteenth Indiana Science Talent Search and on Indiana Science Fairs. He noted that 197 Indiana High School seniors completed entry requirements for the talent search and 31 were designated as finalists. These finalists and their sponsoring teachers were invited to the Junior Scientists' Assembly in Indianapolis on March 18 and 19, 1960. Seventeen were declared winners in the Search. Vernon Cripe of South Bend Central was cited for having sponsored ten finalists through the thirteen years of the Indiana Science Talent Search.

Indiana Science Fairs—Ten Regional Science Fairs were held in Indiana in the spring of 1960 and each designated two finalists to the National Science Fair held in Indianapolis on May 11-14. The organization of Science Fairs in Indiana is such that every junior or senior high school student has the opportunity to participate in a regional fair if he so wishes. The generous support from many quarters for the Science Fairs is deeply appreciated.

The new Administrative Committee of Junior Activities approved by the executive committee in the spring meeting has been appointed and Chairman Paul Klinge announced that they will hold their first meeting today.

After some discussion of the rising costs of printing the *Proceedings* and the increased cost of dues to members, it was decided to raise the price of the *Proceedings* to non-members to $5.00 beginning with Vol. 70. The meeting adjourned at 10:45 P. M.

Respectfully submitted,

WILLIAM W. BLOOM, Secretary

Approved October 7, 1960.

FALL MEETING

GENERAL SESSION

FRIDAY, OCTOBER 7, 1960

9:30 A. M.

The regular annual meeting of the Indiana Academy of Science was held in the Chapel in the Administration Building of Manchester College, North Manchester, Indiana, on October 7, 1960 at 9:30 A. M. The meeting was called to order by President A. T. Guard. Dr. A. Blain Helman, president of Manchester College, welcomed the Academy to the campus and emphasized the role of the members as teachers and scientists in working toward a solution of the great problems that confront the world and our country. The minutes of the Executive Committee meeting of Thursday, October 6, were read by the secretary and approved as read. Dr. Will E. Edington presented the report of the necrologist in which he gave a brief biographical sketch of the following seven members who had died since the last annual meeting:

Norval E. Adams	Theodor K. Just
Eldo H. M. Clauser	George S. Meikle
Martha Doan	John White
Charles M. Ek	

Dr. Marion E. Hodes, Assistant Professor of Medicine and Biochemistry at Indiana University Medical Center, presented an address on "The Status of Cancer Research in the United States, with Special Reference to the Work at Indiana University Medical Center." Following the presentatoin of the address the meeting was adjourned and section meetings followed.

Respectfully submitted,

WILLIAM W. BLOOM, Secretary

FALL MEETING

DINNER MEETING

October 7, 1960

The annual dinner meeting of the Indiana Academy of Science was held in the Oakwood Dining Room of Manchester College. Dr. Lawrence H. Baldinger, Vice-President of the Academy, presided. He introduced the guests at the speaker's table and called upon Dr. A. T. Guard to make special recognition of members with fifty years or more of membership in the Academy. Dr. M. S. Markle, who has been a member for fifty years, was present and warmly acclaimed by the members.

Dr. Willis Johnson, as chairman of the Nominating Committee, submitted the following names as candidates for the offices of the Academy and they were elected.

President.....L. H. BALDINGER, Notre Dame University
Vice-President.....HARRY G. DAY, Indiana University

Secretary.....WILLIAM W. BLOOM, Valparaiso University
Treasurer.....KERMIT H. CARLSON, Valparaiso University
Editor.....RICHARD A. LAUBENGAYER, Wabash College
Press Secretary.....F. N. YOUNG, Indiana University
Trustees.....WARD J. RICE, WILLIAM A. DAILY (to fill the unexpired term of J. E. SEYBERT)
Bonding of Trustees.....SCOTT MCCOY and F. J. WELCHER

Dr. Johnson announced the names of the Chairmen of the various sections. They are as follows:

Anthropology.....JAMES H. KELLER, Indiana University
Bacteriology.....GORDON MALLETT, Eli Lilly
Botany.....JOSEPH HENNEN, Indiana State Teachers College
Chemistry.....WARREN BRANDT, Purdue University
Entomology.....R. E. SIVERLY, Ball State Teachers College
Geography and Geology.....DUNCAN MCGREGOR, Indiana Geological Survey
History of Science.....T. G. YUNCKER, DePauw University
Mathematics.....MERRELL E. SHANKS, Purdue University
Physics.....HOWARD BLACK, Indiana State Teachers College
Plant Taxonomy.....MRS. HELENE STARCS, Health and Hospital Corporation of Marion County
Zoology.....L. E. DELANNEY, Wabash College

Dr. L. E. DeLanney, Chairman of the membership committee, presented the applications of fifty-one individuals for membership in the Indiana Academy of Science and one club for membership in the Junior Academy of Science. The applications were accepted.

Dr. Winona H. Welch, as Chairman of the Resolutions Committee, presented a resolution, which was approved, expressing the appreciation of the Academy to Manchester College and its staff for their work in making this meeting so effective; to Professor Eiffel Plasterer for his entertaining part in the dinner program; and to the officers of the Academy and the division chairmen.

Following the business session Professor Eiffel G. Plasterer presented a dramatic exhibition of "Whirling Lights" from Pendulums Fantasia and Dr. A. T. Guard presented his Presidential Address: "Recent Approaches to the Study of Plant Structure."

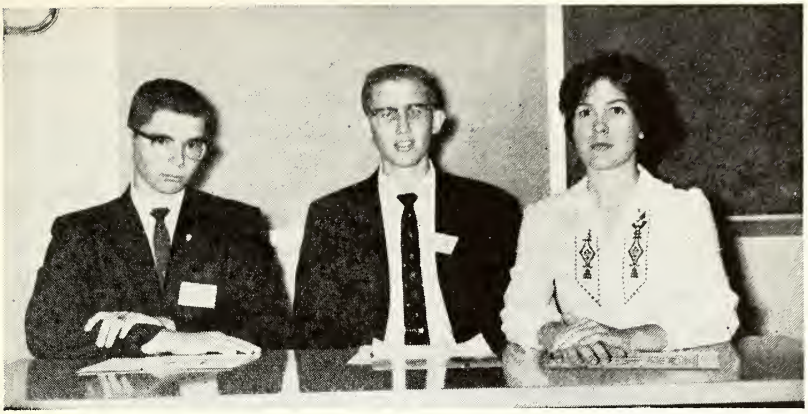
The meeting was then adjourned.

Respectfully submitted,
WILLIAM W. BLOOM, Secretary

NEW MEMBERS

Ashcraft, James S., 3606 E. Michigan St., Indianapolis, Ind. Z
Baker, Wm. Wilson, Box 424, Earlham College, Richmond, Ind. Z
Baumgardner, Marion F., 404 Wood St., West Lafayette, Ind. SS
Bennett, D. Page, Sigma Nu, DePauw University, Greencastle, Ind. Bo
Bloom, Anna G., 1002 Oak St., Valparaiso, Ind. Bo
Brambel, Prof. Charles E., University of Notre Dame, Notre Dame, Ind. C
Brock, Dr. Thomas D., Indiana University, Bloomington, Ind. Ba
Brooks, Austin, Jr., Wabash College, Crawfordsville, Ind. Bo
Brown, Cyril B., 127-9 Marshall Drive, West Lafayette, Ind. SS
Brown, Earle, 301 Caleb Street, Salem, Ind. Bo
Churchwell, Edward B., Box 91, Earlham College, Richmond, Ind. Z, Ph, M
Clark, F. Bryan, 1521 15th St., Bedford, Ind. Bo, SS
Clements, Jeanette N., R. R. 1, Lizton, Ind. Bo
Cole, Carol L., 519 S. W. 2nd St., Richmond, Ind. E, G
Confer, John Earlham College, Richmond, Ind. Z
Cook, Dr. A. Gilbert, Valparaiso University, Valparaiso, Ind. C
Craig, Prof. George B., University of Notre Dame, Notre Dame, Ind. E
Davis, J. Maxwell, 818 S. Rotherwood Avenue, Evansville, Ind.
de Langlade, Ronald A., Purdue University, West Lafayette, Ind. Bo
Dowds, Dr. Richard E., Butler University, Indianapolis, Ind. M
Droste, John B., 1701 Longwood West, Bloomington, Ind. G
Engle, LaMont G., 728 P Street, Bedford, Ind. Bo, SS
Fedynskyj, Mrs. Nathalie, St. Mary's College, Notre Dame, Ind. A
Flanagan, Mary A., Box 71, Ambion, Ind. C
Foley, Arlene F., 520 Central Avenue, Anderson, Ind. Z
Gohlke, Arthur F., 109-12 State St., West Lafayette, Ind. SS
Gorden, Robert W., Box 6, Rolling Prairie, Ind. Z
Henderson, Dr. Norlan C., 2145 College Avenue, Huntington, Ind. Bo
Herrala, Elizabeth A., 736 E. 3rd St., Bloomington, Ind. A
Huffman, John L., R. R. 1, Eaton, Ind. Bo, Z
Johnson, Edward R., 710 Lake Shore Drive, Box 40, Chicago, Ill. Z
Johnson, Richard F., R. R. 1, Gaston, Ind. Bo, Z
Jones, R., Purdue University, West Lafayette, Ind. Ps
Kellar, Dr. James H., 1311 N. Fee Lane, Bloomington, Ind. A
Kemp, Dr. Cecil R., Indiana State Teachers College, Terre Haute, Ind. Z
Koontz, Keith C., Box 384, Earlham College, Richmond, Ind. Z
LeMaster, Douglas F., R. R. 1, Markle, Ind. C
Lubin, Dr. Bernard, Ind. Univ. Medical Center, Indianapolis, Ind. Ps
Manske, Paul, Washington University Medical School, St. Louis, Mo. Z
Marks, Gayton C., Box 228, Schererville, Ind. Bo
Marsh, Terrence G., Box 830, Earlham College, Richmond, Ind. E
Mewhinney, James A., 602 W. Wabash Avenue, Crawfordsville, Ind. Bo
Mielke, Paul T., Wabash College, Crawfordsville, Ind. M
Modesitt, Robert E., R. R. 3, Paoli, Ind. SS
Neal, Robert R., Jr., 702 S. Marshfield Avenue, Chicago, Ill. Z
Novak, Dr. Joseph D., Purdue University, West Lafayette, Ind. Bo
Omoto, Miss Constance E., Indiana University, Bloomington, Ind. A
Ostdick, Rev. Thomas, St. Meinrad Archabbey, St. Meinrad, Ind. C, M

Overack, Dr. Daniel E., 10666 N. College, Indianapolis, Ind. Z
Park, Prof. Richard M., 526 Melrose Drive, Whiteland, Ind. M
Rickenberg, Prof. Howard V., Indiana University, Bloomington, Ind. Ba
Shanks, Prof. Merrill E., 1107 Hillcrest, West Lafayette, Ind. M
Smith, Wm. M., 4900 Julian Avenue, Indianapolis, Ind. Bo, Z
Snow, Brian, 804 E. Walnut, Kokomo, Ind. Ph
Stivers, Dr. Russell K., Purdue University, West Lafayette, Ind. SS
Taylor, Irvin E., 2156 Admiral Drive, Indianapolis 18, Ind. C
Taylor, Morris D., 201-2 Nimitz Drive, West Lafayette, Ind. Ph, C
Thompson, Ian B., University of Leeds, Leeds, England. G
Tovazzi, Prof. Gino, Villa Concordia, Mira, Venezia, Italy. C
Ventresca, Prof. Dante L., R. R. 2, Brownsburg, Ind. Bo, Z
Walcher, Dwain, Indiana University Medical Center, Indianapolis Ind. Ba
Wiersma, Prof. Dan, West Lafayette, Ind. SS
Wilcox, Gerald E., 1957 Indian Trail Drive, Lafayette, Ind. SS
Willig, Leslie A., Tri-State College, Angola, Ind. Ps
Woodham, Gregory C., Indiana Univ. Medical Center, Indianapolis, Ind. Z



Officers of the Junior Academy : l. to rt., President, Harvey Scribner, New Albany High School, New Albany ; Vice President, Robert Raymond, Central Junior-Senior High School, South Bend ; Secretary, Ann Burton, University High School, Bloomington.

INDIANA JUNIOR ACADEMY OF SCIENCE

OFFICERS FOR 1960

President: HARVEY SCRIBNER, New Albany High School, New Albany.

Vice-President: ROBERT RAYMOND, Central Junior-Senior High School, South Bend.

Secretary: ANN BURTON, University High School, Bloomington.

Members of the Council: Ernest Litweiler, South Bend (1956-1960) ; Mrs. Elizabeth Crider, Indianapolis (1957-1961) ; Robert Weber, Fort Wayne (1958-1962) ; Sister Suzanne, Vincennes (1959-1963) ; V. C. Cripe, South Bend (1960-1964).

PROGRAM OF THE TWENTY-EIGHTH ANNUAL MEETING

OCTOBER 8, 1960

Hall of Science, Manchester College, North Manchester, Indiana

8:30-10:00 A. M. Registration and Placement of Exhibits, Room 108.

10:00-11:00 Conferences in Science and Mathematics by faculty representatives of Manchester College.

11:00-12:00 Noon. Visits to Instructional Facilities and Laboratories of Manchester College.

12:00 Luncheon at the College Cafeteria.

1:15 p. m. General Assembly, Chapel of the Administration Building. Greetings, President A. Blair Helman, Manchester College. Business Meeting. Election of Officers and Presentation of Awards.

1:45-4:30 Program of Papers, Harvey Scribner presiding.

The following papers were read by members of the Junior Academy:

1. Nipkow-Blanc Semi-Electronic Television System, Theodore V. Blanc, Shawe Science Club, Shawe Memorial High School, Madison.

2. Effect of RF on Tumor Growth in Rats, Harvey Scribner, Science Club, New Albany High School, New Albany.
3. Basic Stannous Phosphates, David C. Herrick, National Scientific Honor Society, Bloomington High School, Bloomington.
4. Number Systems and Computers, Frances Walker, Aquinas Science Club, Washington Catholic High School.
5. A Duplication of a Land Experiment Relating to a New Theory of Color Vision, Sue Hendricks, Junior Academy, University High School, Bloomington.
6. Some Observations of Chick Embryos, Susan Hathaway, Senior High School, Columbus.
7. The Effects of X-Radiation on Seeds, Stephen Steele, Science Club, Senior High School, Columbus.
8. Synergistic Relationship of Antibiotics and Metals, Patricia A. Coleman, Science Club, Washington High School, Indianapolis.

Exhibit on the Effect of Radio Frequencies on Tumor Growth in Rats; New Albany High School.

9. The Role of the Prophage in the Life of Escherichia coli, Craig Johnson, Science Club, Washington High School, Indianapolis.
10. The Photoreactivation of Amino-Acid-Requiring Mutants in Escherichia coli, Paul Everman, Natural Science Club, Arsenal Technical High School, Indianapolis.
11. Humidity Gradient in a Corn Field, Earl Retherford, Sigma Mu Club, Franklin Central High School, Acton.
12. A Comparative Study on the Effect of Pills on Boys and Girls, Diane Osting, Science Club, Washington High School, Indianapolis.
13. Induced Metamorphosis of Mexican Axolotl, M. Kathryn Crider, Science Club, Westlane High School, Indianapolis.
14. The Influence of Light on the Uptake of C14 by Geraniums, Patricia Kira, Science Club, Washington High School, Indianapolis.
15. Free Energy Determinations in 1-cloro-1-propene, Roger Peters, JETS, Central Junior-Senior High School, South Bend.
16. A Study of Root Initiation, Robert Raymond, JETS, Central Junior-Senior High School, South Bend.
17. Can the Growth Curve of the Common Land Snail Be a Logarithmic Spiral?, Margaret Weir, Adams Walton High School, South Bend.
18. An Analysis of the Vegetation in an Abandoned Gravel Pit, Rick Ferrell, JETS, Central Junior-Senior High School, South Bend.
19. Tropical Fish, Donna Berns, Biology Club, Lew Wallace High School, Gary.
20. Embedding Biological Specimens in Transparent Plastic, Howard Wallace, Adams Waltons, Adams High School, South Bend.
21. Can Hereditary Immunity to Insecticides Be Developed in Drosophila, Edmund Lapham, Adams Waltons, Adams High School, South Bend.

Minutes

The twenty-eighth annual meeting of the Indiana Junior Academy of Science was held Saturday, October 8, 1960 in the Hall of Science of Manchester College, North Manchester, Indiana.

Fifteen exhibits of science projects by high school students were displayed in Room 108, Hall of Science. Exhibits included the following: The Effect of RF Waves on Tumor Growth; The Uptake of Carbon-14 by Geranium Plants as Influenced by Various Light Waves; Determination of Free Energy in 1-cloro-1-propene; Amateur Telescope; Can the Growth Curve of the Common Land Snail Be a Logarithmic Curve?; Embedding Biological Specimens in Transparent Plastic; The Humidity Gradient on Corn; Psychological Effect of Capsules on the Physiological Reactions of Adolescents; Tropical Fish; The Photoreactivation of Amino-Acid-Requiring Mutants in Escherichia Coli; Induced Metamorphosis in the Mexican Axolotl; The Prophage and Its Role in the Life of Escherichia

coli; Paper Cliff Dwellers; The Bee and the Earthworm; and Synergistic Effect of Metals on Certain Antibiotics.

Conferences in science and mathematics were held at 10:00 a. m. by members of the faculty of Manchester College. The science areas represented included biology, chemistry, mathematics, medicine and related fields, physics, and psychology. Following the science conferences each of the participating science staff members also conducted tours through the instructional facilities and science laboratories of the college. The cooperation of the Manchester College faculty in this program was greatly appreciated by club sponsors and members of the Junior Academy.

The annual business meeting was held in the Chapel of the Administration Building beginning at 1:45 p. m. President Harvey Scribner, New Albany High School, New Albany, opened the meeting by introducing Vice President Robert Raymond, Central Junior-Senior High School, South Bend, and Secretary Ann Burton, University High School, Bloomington.

President Scribner then called upon Dr. A. Blair Helman, President of Manchester College, to welcome the Junior Academy on the occasion of its annual meeting. President Helman extended the greetings of the college to the members of the Junior Academy and encouraged them to work diligently in pursuit of scientific as well as other important fields of knowledge.

The next item of business was the election of officers. The Council submitted a list of nominees on a mimeographed ballot from names received from club sponsors. A brief statement about each candidate's achievements in science was included with the listing. After each candidate was introduced, an opportunity was given for nominations from the floor. Since there were no further nominations, the members were asked to cast their ballots. A tabulation of the ballots resulted in the election of the following officers for 1961: President, Stephen Ridgeway, Central Junior-Senior High School, South Bend; Vice President, Mark Schaefer, Central Catholic High School, Fort Wayne; and Secretary, Margaret Weir, John Adams High School, South Bend.

Mr. Ernest Litweiler, reporting for the Council, announced that Mr. Donald R. Winslow, sponsor of the Junior Academy Science Club, University High School, Bloomington, was named the new council member to replace Mr. Litweiler, South Bend, whose term expired this year.

Awards for the "best boy" and "best girl" in science were received by Richard Ferrell, Central Junior-Senior High School, South Bend, and Diane Osting, Washington High School, Indianapolis, respectively. A certificate of merit was presented to each, together with a year's membership in the American Association for the Advancement of Science. Arthur Judd, University High School, Bloomington, and Anne Marie Miller, Central Catholic High School, Fort Wayne, received honorable mention.

An award of $25 was presented to Paul Everman, Arsenal Technical High School, Indianapolis, for the best paper on bacteriology. The presentation was made by Dr. Morris Wagner, Department of Bacteriology, University of Notre Dame, on behalf of the American Society of Bacteriology. Dr. Wagner and Dr. Robert J. Hanson, Department of

Biology, Valparaiso University, served as judges for selecting the best paper presented on bacteriology or microbiology.

Professor H. H. Michaud, State Sponsor, Purdue University, expressed appreciation on behalf of the Junior Academy of Science for the splendid cooperation of Manchester College in providing facilities for the meeting. Special recognition was given Dr. William Eberly, Department of Biology, Manchester College, for his efforts as local program chairman in making the program a success. Professor Michaud introduced the members of the Council and expressed appreciation for their work in preparing the list of nominations for Academy officers and selection of the "best boy" and "best girl" award winners. It was announced also that the next fall meeting of the Junior Academy would be held at Indiana State Teachers College, Terre Haute, on Saturday, October 21, 1961.

The 28th annual meeting of the Junior Academy of Science was attended by 250 registered members, sponsors, and guests, which was considerably less than during the two previous years. The early date of the annual meeting and distance of travel for many clubs no doubt were responsible for the smaller attendance. However, the quality of papers and exhibits continues to improve and clearly indicates the influence of the many science programs in which the Junior Academy of Science participates, such as science fairs, the state and national science talent searches, and the visiting scientists' program.

Twenty of the papers listed on the program were read at the meeting. A brief statement of each paper follows:

"Nipkow-Blanc Semi-Electronic Television System" was the title of the first paper presented on the afternoon program by Theodore V. Blanc, Shawe Memorial High School, Madison. The speaker gave a short history of television followed by an explanation, with diagrams, of his Nipkow-Blanc Semi-Electronic Television System.

"The Effect of RF Tumor Growth in Rats" was reported by Harvey Scribner, New Albany High School. The methods used and effects of radio frequencies in the treatment of tumor growth in rats were explained.

David Herrick, Bloomington High School, related the experimental work done on "Basic Stannous Phosphates," a product of the stannous fluoride found in Crest toothpaste. The investigations were done as a part of the High School Science Institute at Indiana University under the direction of Dr. William Nebergall.

"Number Systems Used by Computers" was reported by Frances Walker, Washington Catholic High School, Washington. The binary system was explained as one of the systems used by computers.

By duplicating an experiment performed by Edwin Land, Sue Hendricks, University High School, Bloomington, explained how she was able to produce color by projecting black and white slides on a screen. The title of her paper was "Duplication of a Land Experiment Relating to a New Theory of Color Vision."

Stephen Steele, Columbus High School, reported on, "The Effects of X-Radiation on Seeds." The purpose of the experiment was to determine the effects of different strengths of X-radiation on the growth of plants.

"The Synergistic Relationship of Antibiotics and Metals" was the title of the next paper presented by Patricia A. Coleman, Washington

High School, Indianapolis. It was concluded from the tests used that three of the antibiotics were more effective when used with metals. Terramycin, however, did not produce the same results when used with metals.

Craig Johnson, Washington High School, Indianapolis, discussed "The Role of the Prophage in the Life of Escherichia coli. He concluded from his experiments that a prophage can cause a genetic change in bacteria.

The next paper by Paul Everman, Arsenal Technical High School, Indianapolis, discussed, "The Photoreactivation of Amino-Acid-Requiring Mutants in Escherichia coli." The paper was judged the best presentation on bacteriology at the annual meeting.

"Humidity Gradient in a Corn Field" was the topic reported by Earl Retherford, Franklin Central High School, Acton. Variations in humidity in different months of the growing season and during different parts of a 24 hour period were recorded. Differences due to topography were also noted. Graphs were prepared to show the humidity gradients in the months of June and September.

An interesting experiment on "A Comparative Study on the Effect of Pills on Boys and Girls" was discussed by Diane Osting, Washington High School, Indianapolis. It was found that some students exhibited physiological reactions to capsules that contained nothing but powdered sugar. It was concluded therefore, that the taking of a capsule, which was a sugar pill, had a definite psychological effect upon their physical reactions.

Kathryn Crider reported on "Induced Metamorphosis of Mexican Axolotl." She discovered that thyroid activators could be used successfully to induce metamorphosis in the Mexican Axolotl. Otherwise, this species of amphibian in its native habitat near Mexico City remains all its life a gill breathing water dweller and breeds in the larval condition.

"The Influence of Light on the Uptake of C14 by Geraniums" was presented by Patricia Kira, Washington High School, Indianapolis. She reported that geranium plants were covered with various colors of cellophane paper to determine the influence of light differences on the uptake of C14. It was found that red light compared favorably to direct sunlight but that blue light practically inhibited the uptake of carbon-14.

Roger Peters, Central Junior-Senior High School, South Bend, analyzed some of his theories concerning "Free Energy Determinations in 1-Cloro-1-Propene," using the latter as the title of his paper.

"Can the Growth Curve of the Common Land Snail Be a Logarithmic Spiral" was presented by Margaret Weir, Adams High School, South Bend. She said her objective was to prove that the common land snail, similar in appearance to the nautilus, is also a logarithmic spiral and not merely a geometric progression. Some progress was made toward proving this objective but further study was needed for conclusive proof.

Rick Ferrell, Central Junior-Senior High School, South Bend, presented an illustrated study of "An Analysis of the Vegetation in an Abandoned Gravel Pit." From his examination of the vegetation and other environmental factors in the gravel pit he concluded that the organic content of the soil correlates with the abundance of plants but that soil moisture was the primary factor in producing vegetation.

While tropical fish culture is an interesting hobby, there are many valuable scientific lessons to be gained from rearing these colorful fishes as related by Donna D. Berns, Lew Wallace High School, Gary. In her paper entitled "Tropical Fish" she reported that special environmental conditions were necessary such as a controlled temperature, constant aeration, suitable plants, freedom from impurities in the water, and constant guard against fish diseases and parasites.

The next paper, entitled "Embedding Biological Specimens in Transparent Plastic," was read by Howard Wallace, Adams High School, South Bend. He described the type of plastic and the procedure used in embedding biological specimens in transparent plastic.

A final paper was submitted on "A Study of Root Initiation" by Robert Raymond, Central Junior-Senior High School, South Bend. The purpose of the study was to determine the nature of the substance responsible for inhibition of root development on cut stems of pea seedlings after three days germination.

INDIANA JUNIOR ACADEMY OF SCIENCE CLUBS

FALL 1960

Town	*School and Club*	*Sponsor*
Acton	Franklin Central, Sigma Mu (1957)	Jerry Colglazier
Bloomington	H. S., National Scientific Honor Society (1931)	Merril L. Crisler
Bloomington	University H. S., Jr. Academy (1938)	Don R. Winslow
Chesterton	H. S., Science (1954)	Robert McCord
Clarksville	Our Lady of Providence H. S., Phy-Chem (1956)	John Chilks
Clayton	H. S., Jr. Academy (1951)	Howard C. Leslie
Connersville	Alquina H. S., Science Club (1960)	Walter Gronning
Columbus	Senior H. S., Science Club (1958)	L. N. Carmichael
Crawfordsville	H. S., Up-N-Atom (1950)	David Wells
Edinburg	H. S., The Alchemists (1954)	S. C. Harrell
Elkhart	H. S., Jr. Academy (1940)	Robert Mahan
Evansville	Reitz Memorial H. S., Phi Chi Mu (1958)	Sr. Francetta Sr. Peter
Fort Wayne	Central H. S., Biology (1940)	Iva Spangler
Fort Wayne	Central Catholic H. S., Albertus Magnus Science Club (1952)	Sr. M. Magdelen, S. P. Sr. Jean Margaet, S. P.
Fort Wayne	Elmhurst H. S., Phy-Chem (1935)	Ruth Wimmer
Fort Wayne	North Side, H. S., Nature (1936)	Vesta Thompson
Fort Wayne	South Side, H. S., Jr. Academy of Science (1956)	Robert Weber Don Weaver
Gary	Edison, H. S. Beaker Breakers (1949)	Mrs. Martha Connor
Gary	Lew Wallace H. S., Biology (1935)	Lola Lemon
Gary	Lew Wallace H. S., Klub Kem (1941)	Mrs. Helen McKenzie
Gary	Tolleston H. S., Biology (1952)	John Reidel

Gary	Tolleston H. S., Future Scientists of America (1949)	Arthur Kline
Gary	Wirt H. S., Biology (1945)	Mrs. Frances Huddleston
Gas City	Mississinewa Joint H. S., Science (1936)	Roy McKee
Griffith	H. S., Science (1953)	George M. Bunce
Hamlet	H. S., Science (1954)	Lawrence Cushman
Hobart	H. S., Science (1952)	Lola Stewart
Indianapolis	Ladywood School, Guerin Science Club (1957)	Sr. Pauline Marie Sr. Louise
Indianapolis	St. Agnes Academy, Science (1959)	Sr. Amelia
Indianapolis	Shortridge H. S., Naturalists Club (1947)	Robert A. Weaver
Indianapolis	Shortridge H. S., Science (1931)	Mrs. H. A. Parker
Indianapolis	Technical H. S., Nature (1932)	Chas. E. Russell
Indianapolis	Howe H. S., Science (1949)	Jerry Motley
Indianapolis	Washington H. S. Science (1931)	Mrs. E. H. Crider
Indianapolis	Westlane Jr. H. S., Science (1959)	John Van Sickle
Jeffersonville	Clark and Floyd County Seminar (1959)	Harold E. Cook 1019 Springdale Dr. Jeffersonville
LaPorte	H. S., Bi-Phi-Chem (1958)	Francis M. Gourley Byron Bernard
Lebanon	H. S., Jr. Explorers of Science (1953)	Helen Reed
Loogootee	St. John H. S., Science (1959)	Sr. Mary Ellen
Madison	Fr. Michael Shawe Memorial High School, Shawe Science Club (1957)	T. A. Winkel
Mishawaka	H. S., Science (1936)	Darl F. Wood
New Albany	H. S., Science (1935)	Erwin Steinkamp
New Castle	H. S., Science (1947)	Betty Jo Montag
New Haven	H. S., Phi-Chi (1954)	Keith Hunnings
Oldenburg	Immaculate Conception Academy Heterogeneous Geniuses (1958)	Sr. M. Constance
Richmond	H. S., Science (1950)	Von Alexander
Rossville	H. S., Science (1954)	Martin Silverthorn
Sandborn	H. S., Up and Atom (1954)	Paul Carter
South Bend	Central H. S., JETS (1939)	V. C. Cripe
South Bend	John Adams H. S., Adams Walton (1953)	Ernest Litweiler
Vincennes	St. Rose Academy, Sigma Tau	Sister Suzanne
Washington	Washington Catholic H. S., Aquinas Science Club (1958)	Sr. Marian Francis

NECROLOGY

Will E. Edington, DePauw University

Norval Emerson Adams

Huntington, Indiana
January 30, 1898

Elkhart, Indiana
July 21, 1958

The Junior Academy of Science was founded in 1931 by the Senior Academy in order to encourage the organization of high school science clubs and to stimulate the work of those clubs already in existence. Obviously the success of the Junior Academy would depend on the cooperation of enthusiastic high school teachers as sponsors of the local clubs, since the sponsors would plan and direct the preparation of scientific papers and science exhibits by high school students for presentation at the annual meetings under the auspices of the Senior Academy. In 1940 the Biology Club of Elkhart High School became a member of the Junior Academy and its sponsor was Norval E. Adams. This club immediately became one of the most active clubs in the Junior Academy so that over the past twenty years Elkhart High School has had two presidents of the Junior Academy as well as two vice-presidents and two secretaries.

Norval Emerson Adams was born near Huntington, Indiana, on January 30, 1898. Following his graduation from Lancaster Township High School in 1916 he began teaching all eight grades in a one room school in Huntington County. He continued this for four years during which time he regularly attended summer school at Manchester College. He then taught two years in a consolidated school and attended summer school at Purdue studying agriculture. In 1922 he began teaching in a junior-senior high school in Huntington County and taking summer school work at Ball State. He received the B.S. degree from Ball State in 1925. He then accepted a position in Elkhart Senior High School teaching biology, where he became Chairman of the Science Department and spent the remainder of his life. During this time he earned the M.S. degree at Indiana University in 1930, and attended Yale University for a summer session as a Fellow in Applied Physiology. He also worked several summers as an assistant to the State Entomologist, and taught civic biology and elementary science workshop at Ball State for several summers.

Mr. Adams was active in national and state educational affairs. He was a member of the National Education Association and the Indiana State Teachers Association. In 1953 he was appointed to a committee set up by the State Superintendent of Instruction to foster conservation education for certain teachers' licenses, and he served three years on a committee to develop an elementary science course of study for Indiana schools. As a member of the National Science Teachers Association he was regional chairman in 1954 of their project for Conservation Education in the United States.

He held memberships in the National Biology Teachers Association, Central Association of Science and Mathematics, United States Biological Survey, Classroom Teachers Association and the Elkhart Teachers Fed-

eration. He joined the Indiana Academy of Science in 1937 and was active in the Junior Academy although the direct sponsorship of the Elkhart High School science clubs was delegated to others after the first few years.

He was interested in 4-H Club work and sponsored clubs while in Huntington County. He was author of a biology manual, *A Study Guide for Applied Biology.*

Mr. Adams did a great deal for science education in Indiana and with his death on July 21, 1958, the state lost a fine educator and citizen with a modern outlook, and the Academy lost a loyal worker in science education for our youth.

ELDO HORACE MANN CLAUSER

Rossville, Indiana — Muncie, Indiana
March 27, 1890 — May 31, 1959

One of the developments of this century not yet sufficiently realized is the application of research to human welfare through sanitation, surgery, antibiotics, clinical diagnosis, psychiatry, hospitalization, and alert, skilful nursing. Reports of spectacular feats in heart surgery, bone transplanting, total blood transfusion in infants, etc., appear frequently in newspapers and magazines. However, only doctors, and especially surgeons, are completely aware of the importance in the ultimate success of their efforts of alert, sympathetic nursing following such operations. Dr. Eldo H. M. Clauser was a physician and surgeon who was deeply interested in the nursing profession, both local and state, and he devoted much thought and time to its improvement. For many years he was chairman of the Executive Committee of the staff of Ball Memorial Hospital, in Muncie, also a member of its Board of Governors, and he regularly taught a class at the Hospital and he took part actively in a few of its workshops.

Eldo H. M. Clauser was born on March 27, 1890, at Rossville, Indiana. After graduating from Rossville High School he began teaching and a year later entered the Indiana State Normal School at Terre Haute. A little later he entered Indiana University and received his Bachelor's degree in 1913 and the M.D. degree in 1915. He spent the next year as an interne in an Indianapolis hospital. In 1916 he opened his office in Muncie as a general practitioner. Following the entry of the United States in World War I he enlisted in the army and was stationed at a base hospital at Camp Sheridan, Alabama. Later he was transferred for service at Camp Eustis, Virginia, and then to Camp Grant, Illinois, where he was discharged on April 1, 1919. He immediately returned to Muncie and reopened his office.

For a number of years Dr. Clauser had a general practice but his principal interest was in surgery and, in 1928, he became a Fellow of the American College of Surgeons and confined his practice to general surgery. He was a member of the American Medical Association and a founding member of the United States committee of the World Medical Association. He had also served as a member of the Board of Governors of the American College of Surgeons and was a past-president of its Indiana Chapter. He was chairman of the Indiana Hospital Licensing Committee from its

beginning. Until his final long illness he had been chairman of the Executive Committee of the Indiana State Medical Association and a member of its Council for over twelve years. He had also served as a member of its House of Delegates. He was a member and past-president of both the Delaware-Blackford Medical Society and the Muncie Academy of Medicine. He was also a member of the Board of Governors of Blue Shield.

Dr. Clauser was an active and effective citizen of Muncie. He was a member of the Muncie Chamber of Commerce, Kiwanis Club, American Legion, Muncie Club, Torch Club and the Board of Directors of the Muncie YMCA. He was a Mason, a Shriner and a member of the Universalist Church.

He had an international outlook on medical and health problems. In 1949 he attended a World Medical Meeting in London and again five years later in Rome. In 1952 he attended a meeting of the American College of Surgeons in Panama. Following such trips he and Mrs. Clauser visited most of the European countries and they had also traveled in Canada and Mexico. Nationally he regularly attended meetings of the American Medical Association and the College of Surgeons.

Dr. Clauser became a member of the Indiana Academy of Science in 1941 because of his interest in zoology and Indiana science.

Eldo H. M. Clauser was a fine, outstanding surgeon who did much to alleviate human suffering. His death occurred on May 31, 1959, in the Ball Memorial Hospital which he loved and for which he had done much.

MARTHA DOAN

Westfield, Indiana — Franklin, Indiana
June 6, 1872 — April 15, 1960

Probably Martha Doan had been a member of the Academy continuously longer than any other member in the Academy's history. She joined the Academy in 1896 and at her death on April 15, 1960, she had completed over 63 years of membership. On the completion of her fiftieth year of membership the Academy on October 18, 1946, recognized her "distinguished career as a scientist and her loyalty to the Academy" by making her an Honorary Fellow of the Academy and sending to her a letter of congratulations and recognition.

She was born on June 6, 1872, of Quaker parentage, at Westfield, Indiana. She completed her public school education in the Union High School at Westfield and then entered Purdue where she worked under Dr. W. E. Stone who had come to Purdue in 1889 as Professor of Chemistry and Director of the Chemical Laboratory and later became President of Purdue. Miss Doan received the B.S. degree at Purdue in 1891 and the M.S. degree in 1893. She had taken her work in such a way that she was granted the B.Lit. degree at Earlham in 1892, so that at the age of 21 she possessed three degrees. She entered Cornell University and received the D.Sc. in chemistry in 1896. She accepted a position that Fall in Manual Training High School, in Indianapolis, where she taught chemistry for four years. In 1900 she went to Vassar College, Poughkeepsie, New York, to teach chemistry and be Head Resident of Raymond House residence hall where she remained fourteen years. She came to Earlham in 1915

as Dean of Women and Professor of Chemistry and spent the next eleven years there. While at Vassar she attended a science meeting in Canada about 1906, and in 1911 she went to the Isle of Wight, in the English Channel, where she attended a meeting of the British Association for the Advancement of Science. After leaving Earlham she devoted the next two years to completing the translation of Fritz Poneth's "Radio Elements as Indicators and Other Selected Topics in Inorganic Chemistry," which was published in 1928. From 1929 to 1937 she was Dean of Women and Assistant Professor of Chemistry at Iowa Wesleyan College, Mt. Pleasant, Iowa.

She retired in 1937 and returned to her ancestral home in Westfield, Indiana, where she devoted her remaining years to local civic and church work and the affairs of the Western Yearly Meeting of the Society of Friends besides caring for her aged mother who lived to be ninety-one and whom Miss Doan took on extended trips to Florida and California for her health.

Dr. Doan was a vivacious individual with a keen wit and striking personality that made her an effective dean of women and excellent teacher. She was recognized as a fine chemist and was honored by Purdue in 1950 with the honorary D.Sc. degree. At the meeting of the American Association for the Advancement of Science in Philadelphia in 1951, Sigma Delta Epsilon, national fraternity for graduate women in science, awarded her a Certificate for outstanding service. She was also given an Alumni Citation by Earlham College in 1952.

Miss Doan was a member of the American Association for the Advancement of Science for 51 years. She was a life member of the American Association of University Women and the National Association of the Deans of Women. She was also a member of the American Chemical Society and Sigma Xi.

She was blessed with good health and remained vigorous and active with her mind keen and alert until the end of her life. While on a visit to a nephew in Franklin, Indiana, she was stricken and died on April 15, 1960.

Martha Doan had a national reputation as a chemist, educator and dean of women. In the Indiana Academy of Science her name will henceforth be associated with the names of Lillien Jane Martin and Agnes Ermina Wells who brought honor and distinction to the Academy.

CHARLES MARION EK

Cassville, Indiana — Spencer, Indiana
June 20, 1873 — January 31, 1960

Charles Marion Ek solved his problem of retirement by returning to the study of botany which had been his major subject as a student in Indiana University. He became acquainted with Ray Friesner, John Potzger and Charles Deam and frequently accompanied them on field trips in the state. During his active years, after retirement, he often made three to five trips a week seeking new specimens, or variations in species, particularly the grasses, as his interest was largely in taxonomy.

He was born on June 20, 1873, at Cassville, Indiana, a few miles north of Kokomo, and he spent most of his life in that area. Following his graduation from Kokomo High School in 1894 he entered Indiana University and received the A.B. degree in 1900. He spent the next nine years as a school teacher, six of these years in Howard County and the other three in a small country school near Pittsburgh, Pa. He then became a timekeeper in the Kokomo factory of the Pittsburgh Plate Glass Company and remained with that company until the Kokomo plant was closed in 1930. He retired some time later and took up botany as his hobby. In 1943 he suffered a stroke that left his right arm partially paralyzed and otherwise incapacitated him. Although then seventy years of age he trained himself to write with his left hand and continued his work in botany and general reading in many subjects. He finally built up a library of over 2,000 volumes. As he approached the age of 80 he left Kokomo and went to live with a son near Spencer, Indiana, where he died in his sleep on January 31, 1960.

He joined the Indiana Academy of Science in 1940 but previous to this he had worked with John E. Potzger on a joint paper presented to the Academy in 1938. Abstracts of a paper in 1941 and a joint paper with Ray C. Friesner in 1943 appear in the Proceedings of the Academy. Although seldom able to attend Academy meetings after his stroke, he maintained his contacts with botanists and continued his interest in the Academy. During his active years he gave many lectures before clubs and other groups, and his advice on and knowledge of botany was always available to anyone who consulted him.

Charles M. Ek was a good amateur botanist with a deep interest in this science which brought happiness to himself and others.

THEODOR KARL JUST

Gross Gerungs, Austria — Chicago, Illinois
October 27, 1904 — June 14, 1960

With the death of Theodor Karl Just on June 14, 1960, at the early age of fifty-five, following five months of illness, there passed an excellent scientist, and the Academy lost one of its living outstanding past presidents. He was born in Gross Gerungs, Austria, on October 27, 1904, and after completing five years in the Grammar School and eight years in the Gymnasium at Krems, Austria, he entered the University of Vienna in 1923. He received the Ph.D. degree in 1928, in botany. During his last year at the University he became acquainted with Father Francis J. Wenninger, also a native of Austria, and Head of the Department of Biology at Notre Dame University, who had spent the year 1927-1928 at the University of Vienna completing his work for the doctorate in Zoology. Father Wenninger, who was also Dean of the School of Science at Notre Dame, was greatly impressed by Dr. Just and invited him to come to Notre Dame. Following a year as an assistant in the Herbarium of the Museum of Natural History in Vienna and a botanical collecting trip of two months for the Museum in the Ionic Islands and Peloponnesos, Greece, Dr. Just came to Notre Dame in September, 1929, as an instructor in biology and assistant curator of the Botanical Libraries and Herbaria.

At Notre Dame Dr. Just became closely associated with Father Julius A. Nieuwland, who had founded the *American Midland Naturalist* in 1909 and was still its editor, and Dr. Just was appointed assistant editor in 1930. He was promoted to Assistant Professor of Botany in 1932, Associate Professor three years later, and Professor in 1940. He became editor of the *American Midland Naturalist* in 1935, and, following the death of Father Nieuwland in 1936, he became Curator of the Botanical Libraries and Herbaria. With the death of Father Wenninger in 1940 Dr. Just was made Head of the Department of Biology. In 1945 he became the J. A. Nieuwland Research Professor in Botany. He left Notre Dame in 1946 to become Associate Curator of the Department of Botany in the Chicago Natural History Museum. He was appointed Chief Curator the following year, which position he held until his death. Dr. Just became an American citizen in 1938.

In 1938, while at Notre Dame, Dr. Just was appointed Scientific Director of the Lloyd Library and Museum, in Cincinnati, and he immediately founded and became editor of *Lloydia*, a quarterly journal of biological science. He continued as Scientific Director and Editor until his death. In 1944 he founded the *American Midland Naturalist Monograph Series* and edited it during the next three years. He also served as an assistant editor of *Chronica Botanica* from 1940 until his death. During his years as editor of the *American Midland Naturalist* he developed it from a small journal with a very limited circulation into an internationally known publication of several hundred pages in six issues annually. During his last year at Notre Dame he was a member of the Graduate Council.

During his tenure at Notre Dame he made during the summers a number of botanical collecting trips over most of the United States. In World War II he was a consultant to the Office of Strategic Services. He served also as chairman or member of various committees of the National Research Council and the National Science Foundation.

After he went to Chicago he became a Research Associate in the Department of Biological Sciences, Northwestern University, in 1947, and a Professorial Lecturer in the Department of Botany, University of Chicago, in 1951, and he retained these connections until his death. During this period he at one time or another gave courses in Paleobotany and Evolution at Northwestern University and also conducted a graduate seminar in Systematics, Ecology, and Biogeography. He edited the *Paleobotanical Report* from 1953 to 1957.

His principal research was in paleobotany and he published over 60 articles in this field. He wrote numerous book reviews and various other articles as part of his editorial work. He wrote comprehensive memorials to his close associates and friends, Fathers Nieuwland and Wenninger, both of whom died as he died, in their fifties at the height of their powers.

Dr. Just was a member of the Botanical Society of America, Torrey Botanical Club, Ecological Society, Sullivant Moss Society, Sigma Xi, and several local societies. He served as chairman of the paleobotanical section of the Botanical Society in 1948 and secretary of the Society for the Study of Evolution from 1949 to 1952. He joined the Indiana Academy of Science in 1929, was made a Fellow in 1933, Vice-President in 1942,

and President in 1943. He presented six papers before the Academy, two of them joint, but only his Presidential Address and a Brief History of the Department of Biology, University of Notre Dame, appear in the Proceedings of the Academy.

Despite his numerous duties he found time to spend with his family. He also enjoyed working with his camera, translating foreign languages, and listening to classical music.

Theodor Karl Just will be remembered as a dedicated, enthusiastic scientist who was recognized as a scholar by his colleagues and who endeared himself to his friends by his consistently cheerful personality.

GEORGE STANLEY MEIKLE

Milton Hills, New Hampshire — Lafayette, Indiana
May 30, 1886 — March 30, 1960

With the coming of Dr. Edward C. Elliott in 1922 as President, Purdue began to experience a great awakening. Dr. Elliott was a forceful, tactful, diplomatic administrator possessing an ingratiating personality, and he envisioned a great future for Purdue. One of his earliest moves was the complete reorganization of the Graduate Committee in 1924 whereby it became composed for the most part of younger men relatively fresh from graduate school and deeply interested in graduate study and research. Within four years Purdue had a full-fledged Graduate School with a Dean and gave its first Ph.D. in engineering, its first Ph.D. since 1897 which up to 1928 was the only one ever given by Purdue. Dr. Elliott began strengthening the Faculty, enlarging the library, securing more modern equipment, and above all changing the chemistry, biology, physics and mathematics departments from service departments to an independent graduate school status. He also traveled much making greater contacts with industrial leaders and looking for talent. In early 1928 President and Mrs. Elliott were guests of the New York City Purdue Alumni Association at a banquet in their honor where President Elliott met a man who had just completed a tour of 41,000 miles involving nearly 3,000 conferences on the topic of basic research. This man was George Stanley Meikle who, a few weeks later, following a visit to Purdue and a conference with President Elliott, was invited to come to Purdue as Director of Research Relations with Industry, a position newly created for the purpose of promoting more effective contacts between the University and the industries in Indiana. He began his work May 1, 1928.

Mr. Meikle soon learned through conferences with executives that industry was primarily interested in qualified graduates. The Purdue Board of Trustees ruled that "All sponsored cooperative research, except in a rare case of expediency, must perform an educational function." This ruling created problems outside the jurisdiction of the Board according to State and Federal laws, and led to the organization and incorporation of the Purdue Research Foundation on December 30, 1930, with Mr. Meikle as a member and Director. As Research Director his major responsibilities were "the development of an active interest in graduate research among staff members and students; the negotiation of sponsored funds; the initiating of approved projects; and the preservation of new

knowledge." He continued as Research Director until July 1, 1954, at which time he was made a vice-president of the Foundation. He retired as Vice-President of the Foundation in 1956 but continued as Director of the Foundation for three more years.

George Stanley Meikle was born at Milton Mills, New Hampshire, on May 30, 1886. After completing his public school education he entered Worcester Polytechnic in 1906, remained three years, and then became a safety engineer with the U. S. Steel Corporation. In 1912 he joined the laboratory research staff of General Electric Company, Schenectady, N. Y., where he specialized in research with gas-filled lamps. He also completed the requirements for the Bachelor of Engineering and Master of Civil Engineering degrees at Union College, Schenectady, in 1913. He left General Electric Company in 1917 to become a captain in the Chemical Warfare Service, U. S. Army, where he directed research on gas masks. Following his discharge from the Army in 1919, he set up his own consultant company having as two of his clients the U. S. Army and General Electric. From 1926 to 1928 he was research consultant to the Honeywell Heating Specialties Company. Some idea of the magnitude of his work at Purdue from 1928 to 1956 may be gleaned from the fact that some $20,000,000 was acquired from approximately 200 sponsors and distributed through the Purdue Foundation for research designated by sponsors and for over 1,000 graduate fellowships in addition to renewals and expansions. During World War II he cooperated with the government in the coordination and administration of University and Federal War Research.

While with General Electric he worked with such researchers as Whitney, Langmuir and Coolidge. One result of his research led to the tungar rectifier, and working with Langmuir and E. Q. Adams produced the famous joint paper, "Flow of Heat through Furnace Walls; the Shape Factor," in 1913. Some of the procedures discussed in this paper continue in use and because of the importance of this work, the Purdue Research Foundation, in 1956, established the "G. Stanley Meikle Fellowship in Heat Transfer" under the direction of the Dean of Engineering at Purdue.

Mr. Meikle was a Fellow of the American Association for the Advancement of Science and the International Anesthesia Research Society. He was a member of the Society for Engineering Education, Sigma Xi, and an honorary member of the Tippecanoe County Medical Society. He was a Scottish Rite Mason, a member of the Lafayette Rotary Club, and the Beta Theta Pi and Scabbard and Blade fraternities. He had been a member of the Indiana Academy of Science since 1931.

The Purdue Research Foundation will always be a splendid memorial to its first Director, George Stanley Meikle, who died on March 30, 1960, and to Edward Charles Elliott, its originator and great Purdue President, who died less than three months later on June 16, 1960.

JOHN WHITE

Poolesville, Maryland — Terre Haute, Indiana
February 24, 1866 — November 5, 1959

A college or university earns and maintains its reputation through the work of its great teachers. Rose Polytechnic Institute is a fine example

of a college with a small enrollment whose excellent reputation as an engineering school has been built up over the years by such scientists as Thomas C. Mendenhall, Henry T. Eddy, Thomas Gray, William A. Noyes, Clarence A. Waldo, Carl Leo Mees and Arthur S. Hathaway. One of these men was a President of the American Association for the Advancement of Science and five of them were Presidents of the Indiana Academy of Science. The name of John White, who came to Rose Polytechnic in 1903, and who died on November 5, 1959, at the age of 92, must be added to this list as a great teacher, administrator and chemist whose work added lustre to the institution he served so long and faithfully.

John White was born in Poolesville, Maryland, on February 24, 1866. After completing his public school education he entered Johns Hopkins University on a scholarship and received the A.B. degree in 1888. Granted a fellowship, he completed the work in chemistry for the A.M. and Ph.D. degrees in 1891. He began his teaching career that fall as an instructor in chemistry at Cornell University and two years later accepted an instructorship at the University of Nebraska. He was promoted to an adjunct professorship of general and analytic chemistry in 1897 and to a full professorship in 1900. In 1901 and 1902 he spent fifteen months at Ostwald's Physico-Chemical Laboratory in Leipzig, Germany, and in the Federal Polytechnic in Zurich, Switzerland. He returned to Nebraska but in 1903 he went to Rose Polytechnic as Professor and Head of the Department of Chemistry and Chemical Engineering. At Rose Polytechnic he was made Vice-President in 1911, became Acting President during 1919-1921, and again from September, 1929, to January, 1931. He served as Dean from 1921 to 1923 and was Vice-President again from 1931 until his retirement in 1936. Following his retirement he was named to the Rose Board of Managers and served until his death. On the Board he served on the Faculty, discipline, and honorary degrees committees.

Dr. White was active professionally. He was a member of the American Chemical Society and a German chemical society. He joined the American Association for the Advancement of Science in 1907 and was made a Fellow in 1910. He also had membership in the Society for the Promotion of Engineering Education, American Association of University Professors, Sigma Xi, Alpha Chi Sigma chemical fraternity and Beta Theta Pi social fraternity. He was also listed in Who's Who in America. He joined the Indiana Academy of Science in 1925 and was made a Fellow in 1936. He published one paper in the Proceedings in 1925 and he wrote the memorial to Frank Caspar Wagner in 1928. He had not been active in the Academy for many years.

In his earlier years he was author and joint author of a number of scientific papers and in 1901 he published a laboratory manual on qualitative chemistry.

In 1911 Dr. White was appointed to the Board of Directors of the Union Hospital in Terre Haute and he served continuously until 1950 when he resigned and was named an honorary director. During his long service he was President of the Board from 1913 to 1916 and Secretary from 1943 to 1950. At the time of his death he was President of the advisory committee of the Rose Ladies' Aid Society.

Dr. White was honored at Rose Polytechnic in 1952 by the establishment of the John White Tuition Grant. The Alumni Fund Committee named the 1957-1958 school year the John White Year.

John White lived a long and useful life of service to Rose Polytechnic and to the city of Terre Haute. His influence will continue to be felt in the lives of the hundreds of graduates with whom he worked.

PRESIDENTIAL ADDRESS

Recent Approaches to the Study of Plant Structure

A. T. GUARD, Purdue University

First of all I want to express my most sincere appreciation to all members of the Academy who have contributed in any way to the work of the Academy during the past year. It would be a pleasure to mention each one by name; however, it would be almost like calling the roll of the membership. Indeed in not a few instances the list would extend beyond the membership. Certainly as one looks back over the work of our Academy and the names of individuals who have ranked high in their respective fields it is not at all presumptuous to say that we have a proud history.

Proud as this history has been, however, this is not a time to look backward. I am especially grateful that there is now an active interest in our organization because I see for it an increasingly important role in the educational development of our state and more particularly in the fields of science in the state.

True, we find competition for our time and efforts in an increasing number of more highly specialized scientific organizations at the national and even the international level, but none of these are designed, nor are they in position to do for the State of Indiana exactly what our Indaina Academy of Science, with its broad type of organization, is able to do. I see for the Indiana Academy of Science both a tremendous opportunity and a stimulating challenge. In view of the fact that we represent every segment of scientific interest in the state, I feel confident that our Academy will be capable and willing to give to Indiana the kind of sound and progressive scientific leadership which she will so much need in the future.

Now to the subject at hand; namely, recent approaches to the study of plant structure. Some fifteen years ago the late Dr. Neil Stevens, then at the University of Illinois, remarked of the biological sciences that they were progressing so rapidly that what is new today will be obsolete within a few years. He went further to say that if there was one area of the subject which might be regarded as definite and fixed it would be the area of morphology and anatomy.

Certainly the anatomy and morphology of organisms has not changed markedly even within historic times. However, the same might be said for other vital phenomena. There is, however, some difference in our approach to an understanding of plant structures—I speak of plants more specifically because this is the field of my special interest and study. That the same is true in biological fields in general, I have no doubt.

As we are confronted with new problems and as we seek to find a more complete understanding of old problems, we naturally look for new techniques and apparatus to investigate these problems. Conversely as new techniques and new apparatus are developed they suggest new problems and new approaches to old problems.

In such a subject as plant anatomy and morphology this is very much the case. It is my purpose to discuss a few of these examples. As many of you are well aware, one of the peculiar characteristics of higher plants

is the capability of the root tips and the shoot or stem tips to continue growth almost indefinitely and to initiate primordia, or the beginnings of new organs, such as leaves and branches. More recently studies have been directed toward an understanding of the degree of autonomy possessed by the apex. Is it largely dependent upon the influences of the tissue below, or is the apex largely a self-determining growth center in which the number, form and arrangement of organs originating are determined by influences within the apex itself?

Wardlaw (5) and others have investigated the nature of differentiation of organs here by using the fern *Dryopteris cristata*. Ferns are especially well adapted for this type of study because of several characteristics. While many plants have only two or at most four stages of developing leaf primordia at each apex, the ferns have very many primordia in a wide range of stages of development and the total developing apex is unusually large. Another characteristic which makes these plants suitable for such experiments is that the mature leaves may be removed from the short stem to uncover the primordia. This short stem may then be placed in a properly prepared humid container and allowed to grow during rather long periods of time.

In order to determine the influence of the extreme apex and the adjacent primordia on any one primordium that primordium was isolated by micro-sections made on each side of it. Without going further into the details of the experiment, it can be pointed out that if a primordium close to the tip which would normally develop into a leaf was thus isolated it developed not as a leaf but as a stem. If, however, the primordium was allowed to develop until a definite apical cell was formed, before the isolating cuts were made it did develop into a leaf. Here we see a technique employed which indicates the degree of autonomy of the apex. These experiments also showed that there is a stage—and that very early—in which differentiation has gone beyond the point of no return. Here we see a trend in the study of plant structure. An attempt to discover not merely what is the nature of the mature structure, but also what are the forces which result in the origin and final production of these structures.

The nature of the stem and root apices and of the histogen or histogens into which these apices may be resolved has long been a subject of study and controversy. I shall not go into the very long and controversial interpretation of this problem. It may be of interest, however, to mention some more recent developments along this line. Clowes (2), 1958, has postulated what he terms a "quiescent zone"—a cup shaped region—just inside the root cap; at the very apex of the root proper. His data indicate that these cells are not actively dividing or that their rate of division is much slower than the adjacent regions just back of this area. Here he uses a combination of two of the newer techniques of investigation namely radio-active compounds and the production of DNA as an indication of rate of cell division. On this basis he draws his conclusion of a less active dividing group of cells in the quiescent zone. There may also be a concommitant conclusion that the metabolic activity in this zone is higher than the adjacent region. These conclusions have not met with unanimous agreement as yet; however, they do present some very interesting implications. This condition pointed out by Clowes in the root has also been

pointed out by Buvat and others to be present in the stem apex. Here it has been studied somewhat more intently by a number of investigators. Perhaps the French workers have been most aggressive in their investigations. Buvat (1), in particular, has emphasized that there is an apical meristem back of which occurs the initiating ring—meristem. It is this latter which is active in the vegetative growth and where cell division produces new leaf primordia and stem growth while the extreme apical meristem is, as it were, passively carried along. When the change from vegetative to reproductive phases is initiated this more apical group of cells becomes active resulting in the broadening of the apex and the initiation of floral organs instead of leaves. Here again there is not complete unanimity of opinion. There are those who fail to see the distinct areas of the general apex which Buvat and his supporters see.

There are certain basic concepts which have been studied, through the use of tissue cultures of higher plants. One of these is the very significant effect of the apex on plant organization. If one takes a portion of the apex of a plant and grows it on a nutrient medium eventually a root will form and the culture will—if properly cared for—grow into a complete new plant. If, on the other hand, a portion of the plant other than the apex is taken, it will very probably produce a mass of cells which are only a group of homogeneous unorganized parenchymatous cells resembling early stages of what we speak of as wound or callus tissue. If this callus tissue is cultured in the ordinary nutrient medium to which coconut milk has been added, it grows and the cells aggregate until a considerable mass of tissue is formed. Under these conditions there sometimes arises in this mass of tissue, cells which take on the character of xylem tracheids and possibly phloem cells. If such differentiated cells do arise, in some cases this is followed by root formation then shoot formation and eventually a new plant is organized.

These tissue culture experiments may throw considerable light on the importance of the role played by the endosperm in the nutrition of the very young embryo. That coconut milk as well as material from other endosperm tissue used has been shown to be effective in stimulating the embryo may suggest the importance of the endosperm in a role other than merely as a food storage organ for the developing seedling. This sequence of the formation of a mass of tissue followed by a more definite polarity, then the development of root and shoot primordia bears a striking resemblance to what happens in the development of the embryo of a seed.

Wetmore (6) and his students have shown the organizing effect of the apical region on masses of tissue grown in culture. They have grafted buds of lilac in masses of parenchymatous tissue from tissue cultures of the same species. They found that the bud grew and induced the formation of xylem tissue in the mass of homogenous tissue directly below. Here we begin to see some of the basic mechanisms which bring about the organization and differentiation of the stem axis in the plant. We not only see the final organization and morphology of the plant, but also see the interplay of influences which determine the final structure and organization of the plant.

One of the most elusive as well as fascinating problems of the Plant Physiologist is the induction of flowering. The problem of the presence

of a florigen if, indeed!, it is a definite substance has long been studied but yet there is no definite answer as to exactly what it is. Here it seems a better understanding of the anatomical similarities and differences of the apex producing leaves and one of the same species producing a flower or a group of flowers may help to solve the problem. Here the work of Buvat and others indicate that there are certain patterns of development which change as the apex changes from a leaf producing apex to a flower producing apex. According to Buvat and others this central area which earlier showed no, or only limited, cell division now becomes more active. As a result of its activity the apex becomes broader and the primordia—of floral organs are produced much more nearly in a cyclic than in a decussate or spiral manner. Not everybody agrees with Buvat and his coworkers, but if this anatomical fact could be firmly established it should promote a better understanding of the physiology of floral induction. Perhaps the number of cells actually involved in floral induction is much less than has ordinarily been thought to be the case. It may be that the magnitude of the inducing substance or substances is much less than has been looked for.

The electron microscope has enabled us to go much deeper into the nature of protoplasmic structure and the nature and sequence of events in the formation of the cell wall. By properly treating the cell walls of plants either chemically or enzymatically, we are able to observe by means of the electron microscope the actual arrangement of these cellulose microfibrils of the cell wall. Frey-Wissling (3) studied this problem several years back and noted that the first microfibrils laid down were in a very irregular arrangement. He also noted that microfibrils laid down later seemed to follow a particular pattern usually parallel and at an oblique angle to the long axis of the cell. He applied the earlier used terms, primary wall and secondary wall respectively to these. As Dr. Nisbet demonstrated in our laboratory this is not in accord with the older and more generally used terms, primary and secondary wall. Indeed!, he found the parallel microfibrils were laid down so close to the tip of the root and so early that to use the arrangement of the microfibrils as a criterion to designate secondary and primary wall would make the terms useless except in a very limited way when studying the sequence of microfibril distribution by means of electron micrographs. It would assign an entirely different meaning to these terms. Already the electron microscope has enabled us to see more intimately the sequnce of events involved in the building up of the cell wall. Eventually it will give us a correct understanding of the nature of the forces and influences which are brought to play upon the formation of the cell wall.

One marvels as they observe the uniformity of development of plants both in form and in the effective timing of the changes which bring about the final development of the individual with such striking regularity. For years almost the entire basis of our taxonomic system was based upon morphological similarity. Obviously this is still one of our mainstays of systematic botany. Genetically we rather casually speak of these characters as gene controlled. Occasionally one of these highly regular growth processes gets out of step genetically—either by mutation or otherwise. It is then they may be studied by comparison of the abnormal with the

normal. This is well illustrated by the paper reported by Postlethwait and Nelson (4) on the anatomical cause of wilting in a genetic strain of corn which wilted even when available soil water was high. Their anatomical investigations showed that this condition arose as a result of the delay or failure to mature of the meta-xylem of the intercalary meristem. This resulted in markedly reducing the water supply to the leaves of the plant. This presents an excellent example of the need for correlation of structural development in both time and place. It also offers an opportunity to study what influence results in the normal development.

The paper presented by Miss Clements in the Botany Section indicates one of the approaches in which we are interested in our own laboratory. Here she has compared anatomically a genetic strain of tomato which does not produce axillary buds with a normal tomato. We hope to carry this experiment further and see if we can discover any biochemical difference between the genetic variant and the normal tomato. We believe that with this approach we can obtain a better understanding of the development of a normal plant.

We might continue almost indefinitely reviewing work that has to do with influences both internal and external which are brought to bear on the plant as it attains its final form. This is enough, however, to indicate that with new apparatus and new technique there are many rewarding fields of study in plant form and structure.

References

1. BUVAT, R. 1952. Structure évolution et fonctionnement du méristéme apical de quelques Dicotyledones. Ann. Sci. Nat. Bot. XI. 13 : 199-300.
2. CLOWES, F. A. L. 1959. Apical meristems of roots. Biological Reviews. 34 : 501-529.
3. FREY-WISSLING, A. K., MUHELTHALER and R. W. G. WYCKOFF. 1948. Microfibrillenbauder Pflanzlichen Zellwande. Experientia. 4 :475-476.
4. POSTLETHWAIT, S. N. and O. E. NELSON. 1957. A chronically wilted mutant of maize. Am. Jour. Bot. 44 : 628-633.
5. WARDLAW, C. W. and ELIZABETH G. CUTTER. 1956. The effect of shallow incisions on organogenesis in *Dryopteris aristata*. Ann. Bot., n. s. 20 : 39-56.
6. WETMORE. 1956. Growth and development in the shoot system of plants. Soc. Devel. and Growth, Symposium. 14 : 173-190.

ANTHROPOLOGY

Chairman: M. S. WADIA, Indiana University

JAMES H. KELLER, Indiana University, was elected chairman for 1961

ABSTRACTS

The Physical Types Occurring in the Historic Illinois (Peoria), Miami, Sauk, and Shawnee Tribes. GEORG K. NEUMANN, Indiana University.—With a reasonably certain identification of series of skeletal material representing proto-historic Illinois (Peoria), Miami, Sauk, and Shawnee tribes, and the development of a varietal classificatory scheme for the Indian tribes that occupied the Great Lakes area, it becomes possible to analyze tribal series according to components and mixtures. Utilizing the following varietal or racial entities: Lenid, Ilinid, Iswanid, Walcolid, and Dakotid, we now can state that the Peoria division of the Illinois were predominantly Walcolid with Ilinid admixture, that the Miami were predominantly Ilinid with slight Walcolid admixture, that the Sauk were a mixture of Ilinid and Dakotid with morphological traits of the former predominating, and that the Shawnee were largely a mixture between Walcolid and Ilinid about evenly divided, and a remnant of the Iswanid variety.

The Identification of a Sample of Unmodified Faunal Remains from the Angel Site. HOLM WOLFRAM NEUMANN, Indiana University.—The identification of a sample of 2,140 bones of vertebrates from refuse deposits at the Angel Site in southwestern Indiana sheds considerable light on the diet of the Middle Mississippi group that occupied the area sometime between 1250 and 1450 A. D. Identification by Class yielded the following proportions: 7.4% birds, 1.3% fish, 0.7% reptiles, 90.5% mammals, and 0.1% unidentified. Among the mammal bones, those of the Virginia deer constituted 87.9% of the total, with only the dog, opossum, raccoon, gray squirrel, and fox squirrel represented by more than 1% each of the total. Although the aboriginal inhabitants of Angel Site were primarily dependent upon agriculture for subsistence, a relatively high utilization of the mammalian fauna in their economy is indicated.

Accelerated Acculturation of Mayan Indians in Guatemala; C. A. FRANCIS X. GROLLIG, S. J., Loyola University.—With the aid of original slides made in 1958 this paper shows many of the visible signs of the acculturation of the Mayan Indians in the Highlands of Guatemala, the Central American republic just south of Mexico. Distances are now calculated in the metric system, and the new roads make possible travel by bus and car, where a few years ago only animal trails and foot paths broke into the isolation of the Indian villages. Village patterns are becoming more compact with houses centered around the traditional village square that follows the pattern introduced by the Spaniards some four centuries ago. Corn is still the dominant item on the menu, but mills and food grinders are replacing the *metate* and *mano*. Pottery is still retained at many hearths, but metal pots and china bowls are beginning to appear

in the adobe households. Additions of powdered milk and vitamin pills to the daily fare certainly indicate acculturation in a new dimension. The most noticeable acculturated item is the dress of the Indians. The *huipiles* (Mother-Hubbard-like plain gowns) of the women are being replaced by western blouses for the women, and for the men shirts are becoming quite common. Great earthmoving machines are crawling into the very heart of Mayaland in the Highlands of Guatemala, and in their wake they leave the Pan-American Highway. This is undoubtedly the greatest single factor responsible for the greatly accelerated rate of the acculturation of the Indians in the remote mountain fastnesses of the Guatemalan Highlands. One of the newest of innovations from the "outer world" is the selection of a queen or two for the *fiesta*. This paper is a documented presentation of the phenomenon now in progress: the accelerated acculturation of an indigenous population.

Change of Incidence of Dental Caries with Dietary Changes in Prehistoric Indian Populations. ELIZABETH A. HERRALA, Indiana University.—The examination of a number of cranial series of prehistoric and historic American Indian populations for alveoloclastic disease and incidence of dental caries revealed an increase in carious teeth in the proto-historic and historic groups. This increase is positively correlated with a change in diet as the transition from a hunting and collecting economy to a mixed hunting and horticultural economy took place.

BACTERIOLOGY

Chairman: WALTER A. ZYGMUNT, Meade-Johnson Research Laboratory
GORDON MALLETT, Eli Lilly and Company, was elected chairman for 1961

ABSTRACTS

Action of Cetyltrimethylammonium Bromide on the Bacterial Cell. WALTER NAKATSUKASA and W. A. KONETZKA, Indiana University.—This investigation was undertaken to study the effects of the cationic surface active agent, cetyltrimethylammonium bromide (CTAB), on bacterial cells in an effort to determine the relationships between disruption of the permeability properties of the cell and the disinfecting action of the compound. The release of 260 mμ-absorbing substances from the cell was dependent on a number of factors, the most significant of which appeared to be the concentration of CTAB and the physiological age of the cells. When the amount of release induced by CTAB was compared to the total content of 260 mμ-absorbing substances (as determined by boiling the cells), there was a correlation between the proportion of the total content released and the effect on viability. These studies indicated that the lethal effect of CTAB was associated with the quantity of essential materials lost from the cell rather than with the disruption of the permeability properties *per se*.

The Influence of Serum on the Cytopathic Effect of Measles Virus. ROBERTO A. MOURA[1] and LILA FERGUSON, Chas. Pfizer & Co., Inc.—When measles virus is grown in tissue culture of various species, its characteristic cytopathic effects are the formation of multinucleated giant cells and the appearance of intracytoplasmic inclusion bodies. It has been found that the species of serum used in the cell culture medium plays a role in the development of these cell alterations. When sheep serum was compared with calf serum as a protein source, it was observed that in the presence of the former, measles cytopathology was remarkably enhanced. Using Edmonston strain of measles virus, a single passage of the HeLa cell line in sheep serum results in greatly increased giant cell formation. On prolonged passage of the virus in cells fed on sheep serum, the cytopathic effect is greatly enhanced over that of sister cells maintained in calf or other sera.

Growth Behavior of Primary Mammalian Cells in Suspension Culture. S. J. CIECIURA, M. E. JEWELL, B. R. HADAR and J. Y. WHITE, Chas. Pfizer & Co.—The ability of a wide variety of *continuous* mammalian cell strains to proliferate in agitated fluid suspensions has been repeatedly demonstrated utilizing a variety of equipment, nutritional media, and environmental conditions. However, the successful cultivation of primary cells under similar conditions is not reported in the literature. Primary dog, monkey, and bovine embryo kidney, and human amnion cells inoculated

1. From the Instituto Adolfo Lutz, Sao Paulo, Brazil, presently in a fellowship at the Chas. Pfizer & Co., Inc.

into 1, 2, 4, 10, 20, and 200 liter vessels proliferate but to only a limited extent. Growth kinetic studies reveal that whereas the total cell population remained fairly constant throughout the course of incubation, cell viability decreased rapidly. Aliquots of these cells incubated as stationary cultures indicate that the number of cells attaching to the glass surface and capable of producing a confluent monolayer is directly proportional to the per cent viability. In contrast, the per cent viability of first passage cells in suspension culture remains high for a short period then decreases slowly. However, the rate of decrease is much slower than that observed with primary cells. Attempts to improve primary cell growth by modifying the serum concentration, initial cell density, and the method of culture "feeding" will be discussed.

A Programmable Multiple Syringe Driver for Use in Metabolic Studies with Filamentous Fungi. M. B. JENKINS and H. R. GARNER, Purdue University.—The Novick and Szilard chemostat is useful for the study of a variety of metabolic problems in bacteria. For some problems involving *Neurospora crassa* it became desirable to attempt to achieve control of concentration of additions to the growth medium similar to that achieved by the chemostat for bacteria. Use is made of the fact that growth rate in *Neurospora* under controlled conditions is quite constant and reproducible. During the period of 50 to 70 hours in which a cube root plot gives a straight line, growth of the mold corresponds in physiological state to that described as logarithmic growth in bacteria. In this period additions at the proper rate can achieve any of the following: (1) maintain a constant level of a metabolized substrate such as a tracer labeled compound, (2) maintain a constant level of a metabolized inhibitor of growth, (3) add a specific required nutrilite as fast as required for growth by a mutant strain, avoiding a higher concentration which may be metabolized by adaptive processes, (4) maintain a constant concentration of an inducer for adaptive enzyme studies. The device constructed achieves these by adding solution to growth flasks as many individual "shots" of a solution of the desired compound from syringes fitted with long hypodermic needles, according to a "program" presented to a photocell relay as holes punched in a long paper tape. The relay activates a motor driving an assembly of twelve syringes, permitting several variables in the same experiment.

Application of Petuely's Medium to the Selection and Differentiation of *Lactobacillus bifidus*. H. L. MURRAY and P. S. PRICKETT, Mead Johnson Research Laboratory.—A phase of our work on enteric bacteria included studies on the selectivity and differentiation of Petuely's medium for *L. bifidus*. In these studies stool samples of both infants and adults as well as pure cultures of enteric organisms were plated on Petuely's agar and incubated under four conditions (aerobic, 10% CO_2, 100% CO_2 and 100% N_2). This medium under anaerobiosis enabled the *L. Bifidus* present in the stool samples to develop without overgrowth by the remainder of the flora. The same selectivity was evident in bifidus-seeded stools of adults that were shown to be initially bifidus-free by this medium. Pure cultures of enteric bacteria either failed to grow or were readily differentiated from *L. bifidus* by their colonial morphology. The common enteric fungus, *Candida albicans*, was readily differentiated from *L. bifidus* by the for-

mer's mycelial production under anaerobic conditions on Petuely's medium. Our results show that this relatively simple medium is a valuable diagnostic tool in studies on the enteric microbial flora.

BOTANY

Chairman: S. N. Postlethwait, Purdue University

Joseph Hennen, Indiana State Teachers College, was elected chairman for 1961

ABSTRACTS

The Use of Maize Mutants to Characterize Normal Development. S. N. Postlethwait and O. E. Nelson, Purdue University.—The investigation of biosynthetic pathways in an organism by analyzing the effect of mutants on various steps in the synthetic sequence has been extremely valuable. A comparable approach to the study of morphogenesis seems plausable and shows promise of being equally rewarding. The many mutants of *Zea mays* provide quantities of material for such a study. Specific mutants which are currently being considered are: knotted (Kn), liguless$_1$ (lg$_1$), liguleless$_2$ (lg$_2$), liguleless$_3$ (Lg$_3$), ramosa$_1$ (ra$_1$), ramosa$_2$ (ra$_2$), polytyptic (Pt), branched silkless (bd), vestigal glume (Vg), and tunicate (Tu).

An Anatomical and Morphological Study of a Sidebranchless Tomato. Jeanette N. Clements and A. T. Guard, Purdue University.—A mutant known as sidebranchless which differs in that axillary buds are not produced was compared with the normally branching Rutgers tomato. It was found that growth during the vegetative phase of both plants is monopodial. In the normal plant, axillary buds first appear at the fifth youngest node with all nodes eventually developing buds. No indication of axillary buds appears in the sidebranchless during this phase. The floral apex first appears as a flattened enlargement which has arisen as a direct continuation of the main axis. Axillary buds are present between the enlargement and the embryonic leaves in both strains. The uppermost bud develops apical characteristics and appears to continue the vegetative axis of the plant. Though the sidebranchless and the normal are similar in regard to this phase, further bud production in the sidebranchless appears only in association with the formation of inflorescences.

Oxygen Production in Some Lakes in Northern Indiana. William R. Eberly, Manchester College.—During the summer of 1960, oxygen production was measured in Myers Lake (Marshall Co.), Shock Lake (Kosciusko Co.), McLish Lake and Taylor Lake (both in Lagrange Co.) in northern Indiana. All of these lakes do now or have in the past been known to possess a plus-heterograde oxygen profile, having what is known as a metalimnetic oxygen maximum. The light-dark bottle method was used to measure oxygen production. Methods of calculating data that can be obtained with this method are discussed. The relationship of the rate of production to the oxygen maximum as well as the influence of such factors as light intensity, temperature, phytoplankton composition, etc., are discussed for each lake.

Effects of Oxygen Level and of Certain Inhibitors on the Respiration of Maize and Rice Root Tips. RAYMOND E. GIRTON, Purdue University.—Respiratory rates in submerged one-centimeter root-tip segments were uniform at 25°C over 2½ hour periods with Qo_2 and Qco_2 values of the order of 6-8 μl/hr/mg. dry weight for both maize and "lowland" rice. Respiratory quotient values for maize were typically lower (0.9±) than those for rice (1.0±). Reduction in oxygen level from 21% to 5% reduced oxygen absorption in maize 60% and in rice 30%. Corresponding values for carbon dioxide evolution were 22% for maize and 26% for rice which resulted, in 5% oxygen, in doubling the R.Q. for maize but no change in the corresponding R.Q. for rice. Raising the oxygen concentration to 100% depressed the R.Q. values, 4% for maize and 14% for rice, by increasing oxygen absorption more than carbon dioxide evolution, which for rice remained essentially unchanged. The transfer of maize root tips from nitrogen to air produced a transitory stimulation in carbon dioxide production of approximately 75% over the average initial rate in nitrogen. When root-tip segments respired in moist air rather than submerged in an aqueous solution, the Qo_2 values increased appreciably: 22% higher for maize and 25% higher for rice. Two respiratory inhibitors, "dieca" and 2,2 dipyridyl greatly curtailed oxygen absorption in air, an average inhibition of about 50% for both maize and rice resulted from a 1 hour pretreatment with 0.001 M dipyridyl. The dieca inhibition was less and ranged from 11% to 27%. The effects of the two inhibitors, when applied simultaneously, were not additive. The inhibitory effect of dipyridyl could be reduced approximately 40%, with maize, by a pretreatment with M/30 sodium citrate solution.

Problems Related to the Giant Saguaro Cactus. ROBERT W. HOSHAW[1], University of Arizona. — The massive columnar saguaro, *Carnegiea gigantea* (Engelm.) Britt. and Rose, forms conspicuous forests in southern Arizona and northwestern Mexico. The decline of this cactus in certain areas has stimulated considerable botanical research recently in an attempt to collect fundamental information about the species. Studies to date have included experimental work by several investigators on the problems of seed germination, seedling establishment, disease control, chemical composition of the plant and a means of age determination. Thus far, these studies have shown that the seeds are light-sensitive, seedling establishment is difficult and in certain regions the bacterium, *Erwinia carnegieana*, is infecting much of the population. Major problems related to saguaro repopulation must be solved to maintain the present limited population in the United States.

The Isolation and Identification of Soil Fungi and Their Relation to Root Rot of Apple. ZOFIA MACIEJOWSKA and E. B. WILLIAMS, Purdue University.—In studies on damping off of apple seedlings preliminary investigations on the relationships between soil fungi from the root environment were made. Four media, V-8 juice, PDA, corn-meal-agar, Ohio medium (fortified with antibiotics and sodium propionate), and two soil

1. National Science Foundation Science Faculty Fellow at Indiana University during 1960-61.

dilutions (10^{-4} and 10^{-5}) were used in every replication. In 1 mg. of fresh soil from a total sample of 50g soil, isolates from 52 genera were found. The isolate of *Sporomia* differed from the commonly described characteristics for this genus by the occurrence of 32 spores in the mature ascus. These arise as the result of fragmentation of four-celled ascospores. Also, the unusual fruiting body of an unidentified fungus was observed. This structure consisted of open apothecium-like cup with a compact, cylindric mass of spores formed inside. The identification of *Isaria* was possible only when the organism was cultured in the presence of *Phytophthora cactorum*. This stimulated spore production by the isolate of *Isaria*. The antagonistic properties of fungi isolated from soil were tested *in vitro* against *Rhizoctonia solani, Pythium ultimum* and *Prytophthora cactorum*. Isolates of eight genera, *Espergillus, Memnoniella, Penicillium, Spicaria, Scopulariopsis, Thielavia,* and two unidentified fungi, were strongly antagonistic to one, two, or the three damping off organisms. Three species, *Spicaria violaces, Thielavia sp.* and *Scopularopsis sp.*, excreted water soluble toxic compounds. The compound excreted by *S. violacea* was separated by means of paper-column chromatography in sufficient quantity for identification. The location of the compound on the chromatograph was determined by placing sterile paper strips in Petri dishes. Liquid PDA was poured over these strips and inoculated with *P. cactorum*. Activity was expressed as inhibition of *P. cactorum*.

Studies on the Biochemical Response of *Malus atrosanguinea* to the Apple Scab Pathogen, *Venturia inaequalis*. R. L. NOVEROSKE and E. B. WILLIAMS, Purdue University.—An investigation of the biochemical nature of resistance in apple to *Venturia inaequalis* is currently underway. *Malus atrosanguinea* 804 is immune to all known races of *V. inaequalis*. Under greenhouse conditions symptoms on this selection are expressed as minute depressions or pits resulting from the death of several epidermal cells at the point of germ tube penetration. These microscopic symptoms are produced within forty-eight hours. This type of reaction is a specific response to *V. inaequalis*, and is not initiated by other pathogens, such as *Podosphaera leucotricha*, or by mechanical injury. Water extracts from heavily inoculated leaves contain a toxin highly inhibitory to germination of *V. inaequalis* spores, whereas water extracts from uninoculated leaves are not inhibitory. Studies on the characterization of this toxin are being conducted. When apple shoots uniformly labeled with C^{14} are inoculated with spores of *V. inaequalis*, a tremendous increase in labeled compounds occurs at the site of penetration. The relationship of these compounds with resistance to scab has not yet been determined.

Stolon Decay of *Mentha* spp. in Commercial Mint Plantings. RALPH J. GREEN, JR., Purdue University.—Peppermint (*Mentha piperita* L.) and the spearmints (*M. Spicata* L. and *M. cardicca* Baker) are propagated from stolons dug in the spring from existing plantings. One of the limiting factors in the production of these crops is variability in the vigor and survival of stolons. The effects of unfavorable winter environment are apparent but little attention has been given to possible fungal deterioration of the stolons in the soil. Surveys of numerous commercial plantings showed that the stolons were subject to extensive deterioration from

lesions of apparent fungal origin. Isolations made from infected stolons showed that *Rhizoctonia* sp. was the most common isolate from these tissues. The incidence of stolon lesions was often so great that few, if any, were completely free from infection. The infected stolons deteriorate in the soil and this undoubtedly is one of the contributing factors in production of stocks for planting purposes.

Further Observations on Apple Virus Diseases in Indiana. GAYLORD I. MINK and J. R. SHAY, Purdue University.—Ten Malus species were tested for their value as sensitive indicators of viruses latent in apple: *M. baccata jackii*, *M. hupehensis* (241-37), *M. micromalus* (245-38), *M. platycarpa* PI203277, *M. prunifolia* (19651), *M. prunifolia microcarpa* (782-26), *M. prunifolia xanthocarpa* (591-25), *M. sargenti rosea*, *M. sieboldii* (2972-72) and *M. zumi calocarpa* (StR1T11). Young trees were inoculated at bud break in the greenhouse by inserting buds or bark tissue into the seedling portion of test immediately below the test bud. The virus isolates used were known to contain chlorotic leafspot, stem pitting, common apple mosaic, dwarf fruit and decline, apple green mottle and Spy 227 lethal viruses, or a combination of certain of these. Species showing most promise as indicators were *M. hupehensis*, *M. prunifolia*, *M. prunifolia microcarpa*, *M. sieboldii* and *M. zumi calocarpa*. Leaf reactions were obtained on these species from 2 to 4 weeks following inoculation. *M. prunifolia microcarpa*, although found to contain the CLSV as a latent, developed discrete line-pattern type leaf symptoms when inoculated with virus cultures believed to contain only the CLSV. In general leaf symptoms incited by virus isolates known to contain CLSV on *M. hupehensis*, *M. prunifolia*, and *M. sieboldii* resembled those of the chlorotic leafspot disease on RI2740-7A. However, exceptions were noted and these are being studied in further detail.

The Biology of *Scolectotrichum graminis* Fckl. Causing Leafstreak of Orchardgrass. GLENN W. COBB and JOHN TUITE, Purdue University.—Research on leafstreak of orchardgrass and timothy has been handicapped by the inability to obtain consistent infection in the greenhouse with pure cultures of *Scolecotrichum graminis* Fckl. This work is primarily an attempt to find ways of increasing inoculum and to obtain successful artificial infection. In addition, aspects of taxonomy, epidemiology, and control of the organism was investigated. To explore morphological variation in the species and to determine if morphological differences were related to reported physiological differences, 16 collections from orchardgrass and timothy were studied for spore length, width and the number of septations.

Vegetation and Environment Along the Wabash and Tippecanoe Rivers. ALTON A. LINDSEY, ROBERT O. PETTY, WILLARD VAN ASDALL and DAVID K. STERLING, Purdue University.—The flood plains studied for 4 years extend through 230 miles of latitude; the resulting climatic difference, the larger size and more fluctuating flow of the Wabash, and the coarser soil texture along the Tippecanoe determine the vegetational differences. Soil is the most uniform environmental factor in the study area. Observations on 629 vascular plant species were recorded on punch cards

for analysis. Aquatic plants are more important in the Tippecanoe, and ruderals more so along the Wabash. Allogenic factors predominated in early seral stages. Detailed phytosociological analyses of 56 flood plain forest stands were made by sampling methods and intensities yielding less than 15% standard error for the dominants. Tolerance to flooding was used in computing vegetational continuum index. The species curves for the various stands showed that the continuum concept applied well to our flood plain latitudinal and ecological gradient. On the Wabash the dominance ranges from bald cypress or post oak in the south to beech—black maple in the north. Cottonwood is much more important on the Wabash, and river birch on the Tippecanoe. Submerging experiments during the growing season showed that second-year silver, red, and Drummond maples were not even defoliated by 8 weeks of continuous complete submergence during the growing period. The duration-summation method revealed the influence of summer heat and winter cold on plant range limits. Climate influences range limits by competitively encumbering certain species relative to others. Field work extended the known range of 7 southern species.

Fern Gametophytes as a Tool for the Study of Morphogenesis

A. G. Kelley[1] and S. N. Postlethwait

The purpose of this paper is to review those features of fern gametophyte morphology which render them uniquely valuable as subjects for the experimental morphologist; and to present the results of a preliminary study on the effects of biotin and ∝-naphthaleneacetic acid (NAA) on vegetative development of *Pteridium aquilinum* gametophytes.

Although not all of the following characteristics are unique to fern gametophytes, the aggregate effect of these characteristics contained within a single type of organism provides a subject of exceptional potential for investigating and analyzing certain basic problems in morphogenesis.

The first point of consideration is that of size. Fern prothalli, which usually range from about ½ to 1 cm. in diameter at maturity, are small enough to be cultured in quantity in a small container such as a petri dish, yet large enough to permit surgical treatment under a binocular microscope, using simple tools. Albaum (2) has taken advantage of this feature to study regeneration in fern prothalli.

Another characteristic is that of the relatively short maturation period of two to six weeks in most species. This allows for fairly rapid evaluation of treatment effects and permits the execution of cumulative sequence experiments in a much shorter period than comparable studies on other photosynthetic land plants.

The next point is concerned with the vegetative development of fern prothalli. In most species of higher ferns, spore germination gives rise to a relatively brief filamentous stage. This is followed by a rather prolonged period of biplanar cell division, during which the prothallus assumes a cordate form as a consequence of the establishment of an apical initial cell. Finally, cell division in the apical region of the prothallus becomes three-dimensional, giving rise to a cushion of cells. Because the prothallus is only one cell layer in thickness during the biplanar stage of division, the following advantages obtain:

(1) Growth can be measured as a function of increase in surface area. As Albaum (1, 2) has shown, this enables the investigator to make a rapid assay of relative development, and to establish precise growth curves for individuals, rather than resorting to approximations from population samplings.

(2) Cell lineages, hence morphological development, can be followed throughout the organism. Dopp's (3) work in tracing the cell-for-cell development of a single prothallus points the way to a direct and comprehensive means for the investigation of growth at the cellular level.

(3) The sequence of effects of chemical or surgical treatments can be observed throughout the entire living organism, without resorting to the conventional method of killing the subject in order to observe it.

In addition to the foregoing advantages resulting from discrete stages in cellular growth patterns, fern prothalli provide a means for

1. This investigation was carried out during the tenure of a Predoctoral Fellowship from the National Cancer Institute, Uninted States Public Health Service.

investigating morphogenesis at the biochemical level. Hotta, Osawa, and Sakaki (4, 5) have investigated the factors underlying the transition from filamentous to two-dimensional growth, and have found it to be reversible with certain amino acid analogs. They further discovered that the onset of the two-dimensional stage is accompanied by the production of a different type of RNA from that of the filamentous stage. This work may eventually provide an important bridge in the gap between what is known of biochemical reactions and what is known of the expression of those reactions at the morphological level.

The final feature deals with the patterns of prothallial development in relation to sex expression. These patterns have been elucidated by Naf (6, 7) who has found them to be related to the elaboration of a morphogen which he terms the antheridial factor. Because the appearance of this factor and its functions are integral to the developmental morphology of the prothalli, its characteristics will be briefly described.

First, it is a discrete biochemical entity, produced by the prothalli of polypodiaceous ferns and subsequently released into the culture medium. It has been demonstrated to be specific for the induction of antheridia, hence the name antheridial factor. The mode of action in the induction process has not yet been clarified, but it appears to function in a system of two, three or more competitive factors. Thus, the term antheridial factor may be more comprehensive than its present application warrants; nevertheless, it will be used in this discussion without further qualification.

Naf (6) has determined the time-course of the production of the antheridial factor which appears as follows in relation to the behavior of prothalli of *Pteridium aquilinum*.

Spores begin germination the second day after inoculation, and continue germinating through the first week. On the seventh day the first heart shaped prothalli are apparent, and on the eighth day the first effective concentration of antheridial factor can be detected; on the tenth day the first antheridia are initiated.

The development of archegonia does not occur until after the cushion of cells develops just behind the apical notch. The initiation of archegonia marks the end of susceptibility to the antheridial factor. That is, once archegonia have arisen on a prothallus, no antheridia can be induced on that prothallus.

The gametophytes in a culture fall into three general categories. The most rapidly growing prothalli produce archegonia, beginning at about the seventh day after inoculation. These gametophytes, "female" prothalli, apparently produce the antheridial factor, which diffuses into the medium and exerts its influence on the less rapidly growing prothalli. Because they have reached the stage of archegonial initiation before effective levels of antheridial factor have been produced, these "female" prothalli are insensitive to the factor and so remain exclusively archegoniate.

The second growth pattern is associated with what will be called "hermaphroditic" prothalli. These, being slower growing than the first group, have not reached the insensitive stage and so produce antheridia in response to the presence of the antheridial factor secreted by the "female" prothalli. They too produce the antheridial factor. However,

presumably because they have developed an apical initial region, they develop into cordate gametophytes, eventually giving rise to an archegonial cushion and losing sensitivity to the factor. The antheridia thereon disintegrate by the time four archegonia are produced. In a mature colony these are usually recognizable only as archegoniate prothalli.

The third growth pattern, giving rise to exclusively antheridium-bearing prothalli, is characteristic of the slowest growing individuals in the culture. These prothalli have not formed an apical meristem at the time the antheridial factor becomes effective. Presumably this precocious production of antheridia retards prothallial growth to such an extent that these gametophytes remain depauperate and perennially antheridiate.

Thus, the previously mentioned work of Hotta and his co-workers opens the way to investigation of morphogenesis at one of its simplest levels of expression, i.e. cell division in a one-dimensional vs. a two-dimensional plane. And Naf's work provides the basis for morphogenic investigation at the much more complex level of sex expression and the attendant growth-differentiation interactions.

A preliminary investigation on response of fern prothalli to growth regulators was undertaken by the authors. Biotin was used because of its function in rapidly growing tissues in carboxylation and decarboxylation in the TCA cycle, and in deamination of amino acids, presumably operating in protein synthesis. NAA was selected on the basis of its auxin activity.

Spores of *Pteridium aquilinum* were seeded on nutrient agar (1%) containing inorganic salts as follows:

Moore's solution

NH_4NO_3	500 mg/1
KH_2PO_4	200 mg/1
$MgSO_4.7H_2O$	200 mg/1
$CaCl_2.2H_2O$	100 mg/1

Nitsch's solution (modified) at 1 ml/1 culture medium

$MnSO_4.H_2O$	3.000 g/1
$ZnSO_4.7H_2O$	500 mg/1
H_3BO_3	500 mg/1
$CuSO_4.5H_2O$	25 mg/1
$NaMoO_4.2H_2O$	25 mg/1
$CoCl_2.6H_2O$	25 mg/1
H_2SO_4 (sp. gr. 1.83)	0.5 ml/1

Biotin and NAA were added after the medium was autoclaved but before it solidified, to give the following concentrations: NAA, 10^{-9}M through 10^{-6}M; Biotin 10^{-6}M through 10^{-3}M; and Biotin at 10^{-6}M or 10^{-5}M in combination with NAA at 10^{-9}M or 10^{-8}M.

The cultures were grown in pyrex petri dishes at 23°C, under ca. 200 f.c. of continuous light (G.E. Standard Cool White fluorescent).

Notes on development were recorded at different intervals for a period of approximately six weeks. At the end of this time, measurements of maximum length and maximum width of prothalli were made, using an ocular micrometer on a dissecting microscope. Some of the materials were judged unsuitable for the collection of size data, owing to variations

attributable to factors in the cultural environment. The measurements were converted to metric equivalents, and the product of maximum length X maximum width was used an an index of surface area, hence growth [after Albaum (1)]. The results are shown in Table 1.

Table 1. Effect of growth regulators on size of *Pteridium aquilinum* gametophytes (6 weeks)

TREATMENT	AVERAGE RELATIVE SIZE (length X width in mm.)	
	"Male" Prothalli	Other Prothalli
CONTROL	1.2	35.0
BIOTIN 10^{-6}M	1.4	31.1
10^{-4}M	1.6	40.0
10^{-3}M	2.2	37.9
NAA 10^{-8}M	1.3	29.1
10^{-7}M	1.2	15.6
10^{-6}M	0.2	1.4
BIOTIN 10^{-6}M NAA 10^{-9}M	1.6	37.6
BIOTIN 10^{-6}M NAA 10^{-8}M	1.2	39.6
BIOTIN 10^{-5}M NAA 10^{-9}M	5.7	39.6

These data reveal three features of possible significance. First, there appears to be a genuine, albeit small, effect of increased growth due to the addition of biotin, especially upon the "male" prothalli. Observations indicate that this stimulation was effected most strongly in the early stages of growth, in which there was a pronounced size increase in the biotin treatments over the controls.

Conversely, there was decided inhibition of growth by NAA at the higher concentrations. This corresponds with the findings of Soussentov (8). Although several of the NAA-treated prothalli in the present study produced antheridia, no archegonia were produced on the prothalli in the 10^{-6}M concentration of NAA. This effect is considered to be indirect, as there was no formation of the cushion of cells which seems to be a prerequisite to archegonial initiation.

Finally, the combined application of biotin at 10^{-5}M and NAA at 10^{-9}M had a pronounced effect on growth of the "male" prothalli. The growth promoting effect of this combination was readily apparent in all treated prothalli from early stages of development. The fact that the measurements made at the end of six weeks' growth do not strongly corroborate these observations suggests that there may be a size limiting factor which tends to equalize mature size of both stimulated and control prothalli. If this is so, the measurements may have been made too late to demonstrate the full effectiveness of the biotin. This suggestion is further implemented by the following observations on the form of the "male"

prothalli. Even in the controls a few of these usually ameristic prothalli produce three, four, or more separate apices, resulting in a rosette of cordate appendages, each of which looks like a typical heart-shaped prothallus in miniature. The frequency of such rosette prothalli was greater in the biotin-treated cultures, and still greater with the biotin-NAA combination. In addition, the latter treatment appeared to stimulate vegetative growth to the extent that one or more of the apices on some prothalli would develop into almost normal-sized cordate prothalli.

From this it is apparent that biotin and, to a greater extent, the appropriate proportions of biotin and NAA stimulate the rate and degree of development of active meristems. It would seem, therefore, that the chief influence is upon the rate of cell division. It may be that there is an additional effect of promoting polar orientation and consequent inception of an apical region of meristematic cells.

Summary

The potential value of fern gametophytes as a subject for studies of morphogenesis lies in their suitability of size; short period of maturation; vegetative growth sequence from filamentous to biplanar to three-dimensional cell division; and patterns of prothallial development in relation to sex expression.

Preliminary studies on the effect of biotin and NAA on prothallial development indicate that NAA at 10^{-6}M inhibits cell division, and has the indirect effect of preventing archegonial initiation. Biotin appears to progressively stimulate growth through the concentration range of 10^{-6} to 10^{-3}M, and the combination of biotin and NAA, particularly at 10^{-5}M and 10^{-9}M, respectively, further promotes growth. It is suggested that this stimulatory effect is primarily upon the rate of cell division.

Literature Cited

1. ALBAUM, H. G. 1938. Inhibitions due to growth hormones in fern prothallia and sporophytes. Amer. Jour. Bot. 25 : 124-133.
2. ———— 1938. Normal growth, regeneration, and adventitious outgrowth formation in fern prothallia. Amer. Jour. Bot. 25 : 37-44.
3. DOPP, W. 1927. Untersuchungen über die Entwicklung von Prothallien einheimisher Polypodiaceen. Pflangenforschung 8 Jena.
4. HOTTA, Y. and OSAWA. 1958. Control of differentiation in the fern gametophyte by amino acid analogs and 8-azaguanine. Exptl. Cell Research 15 : 85-94.
5. ————, ————, and T. SAKAKI. 1959. Ribonucleic acid and differentiation of the gametophytes of a polypodiaceous fern. Developmental Biology 1 : 65-78.
6. NAF, U. 1958. On the physiology of antheridium formation in the bracken fern (Pteridium aquilinum (L) Kuhn). Physiologia plantarum. 11 : 728-746.
7. ————. 1956. The demonstration of a factor concerned with the initiation of antheridia in polypodiaceous ferns. Growth. 20 : 91-105.
8. SOUSSONTOV, I. 1957. Action de trois de auxines synthese sur le developpement in vitro des germination de fougeres. C. R. Soc. de Biol. Paris. 151 : 531-536.

The Organization of the Root Apex of *Glycine max*

C. E. Anderson and S. N. Postlethwait, Purdue University

The purpose of this paper is to compare the pattern of development in the apex of the soybean root with several theories on organization of root apices.

Hanstein (11, 12), in 1868, proposed a theory on apical organization called the Histogen theory. He suggested that the apex is composed of three cytogenerative regions: the plerome, which forms the cortex, the periblem which forms the stele, and the dermatogen, which forms the epidermis. Although these regions are easily distinguished in the roots of many species, some investigators disagree with Hanstein as to their nature. Hanstein proposed that cells, as they are formed at the apex, have had their final form determined. Esau (7) points out that there is no reason to assume that the destinies of different cells of the plant body are determined at their origin. Foster (9), in working with cytochimeras, found that histogenesis and organogenesis have no obligate relationship to the segmentation and layering of cells of the apical meristem. He further pointed out that gymnosperms and some angiosperms show no distinction between the plerome and the periblem.

These same regions were assigned a different name by Haberlandt (13). The stele, in his scheme, is derived from the procambium, the cortex from the ground meristem, and the outermost tissues from the protoderm. The root cap is formed by the calyptrogen. Those who use these terms are rather noncommittal about the origin of the tissues.

Guttenberg (10) advanced the theory that the initials for each region are derived from a single apical cell, with all tissues being ultimately referrable to its activity. In some cases it has been proposed that 2 or 3 apical cells serve as apical initials.

New research methods have enabled experimenters to approach the problem of apical organization in various ways. Clowes and Brumfield have employed some of these new procedures with interesting results.

Brumfield (1) used X-rays to alter the cells of the apex. He found that the resulting pattern of development was not always the same, but one of the more common patterns was a division into three distinct regions (fig. 2). This may indicate that 3 cells are responsible for all tissue formation. It also suggests that the derivatives of one cell may form all the different root tissues.

The validity of conclusions drawn from X-ray treatment has been questioned. Clowes (2) performed a series of experiments to determine the actual effect of X-rays on the root apex of *Zea*. He found that DNA synthesis can be lowered, that mitosis may be delayed, that chromosomes can be broken, at times so badly as to stop cell division altogether, and that disturbances caused by ionization may occur to change the rate of division and upset hormonal processes.

A recent concept of apical organization has suggested a quiescent center or a zone of limited cell division occupying a central position in the apical meristem. (Fig. 1) Clowes (3, 5, 6), by using radioactive tracers in various substances connected with cell division, has shown in *Zea* an area

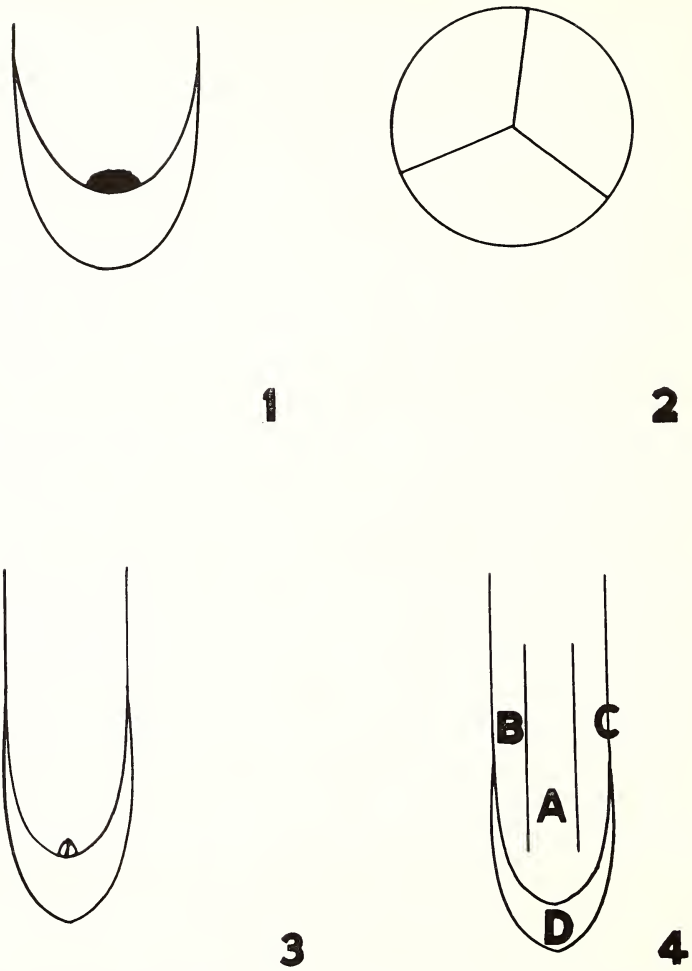


Plate 1. Figure 1. Root diagram showing quiescent center. Figure 2. Chimeral arrangement of root tissues after X-ray treatment by Brumfield. Figure 3. Root diagram showing apical cell as proposed by Guttenberg. Figure 4. In Hanstein's Histogen theory A—periblem B—plerome C—dermatogen. In Haberlandt's theory A—procambium B—ground meristem C—protoderm D—calyptrogen.

in the center of the apex which carries on little or no cell division. The area of peak cell division encircles this inactive center. Support has been offered to this theory by Miller (17) in his study of *Humulus lupulus*, and by Jensen and Kavajian (15) in their study of *Allium*.

The soybean root has in its organizational pattern a stele, cortex, epidermis and root cap. An organized meristem is responsible for the formation of the tissue of the root. The meristem displays some discreet regions of activity, however, in some areas cell division may be somewhat

irregularly distributed. The age of the root and the tissue type causes dissimilarity in the location and number of cell divisions.

Most of the cortex is produced by a single layer of cells which can be distinguished early in the organization of the apex. This layer of cells undergoes a series of periclinal divisions resulting in a radial alignment of its derivatives. The outer layers of cortex, having been derived directly from the periphery of the meristem, do not display this radial alignment. The cortex also shows concentric layering, which Heimsch (14), in studying tomato, considered to result from unison division in the initiating layer. The division in this layer is primarily responsible for the sudden increase in root diameter.

As activity begins in the inner cortical layer, the cells of the stele still appear rather large and inactive. This inactive area is often 6 to 8 cells wide and varies notably in its persistence basipetally. Further study may clarify the extent of this region. The termination of this area is delimited by an increase in cell activity, smaller cells, and ultimately differentiation of primary phloem.

The epidermis of the soybean root arises with the cortical tissue at the periphery of the apical meristem. In its early ontogeny the epidermis is indistinguishable from the cortical tissue. The first modification occurs as the epidermal tissue undergoes a series of anticlinal divisions to form a layer of radially elongated cells. This early elongated shape is not maintained. As the root expands the epidermal cells grow and attain a more isodiametric shape.

The origin of the root cap is somewhat more obscure. Part of the root cap forms from a series of periclinal and anticlinal divisions of tissue located acropetally to the cortical and epidermal initials. The central portion of the root cap, sometimes called columella, appears to have a separate point of initiation. Mann (16) has described the columellar organization in garlic roots as follows: "The root cap has a column of

Plate 2. Photomicrograph of 4-day old soybean root apex showing its apical organization. The magnification is 192 times.

8 to 10 longitudinal rows of cells. At the edges these divide periclinally, extending the cap laterally. The shape and position of the initial cells seem to provide no evidence that these groups of initials are distinct from one another." Clowes (4) found in autoradiographs of *Allium* and *Zea* that the columella is produced by a thin line of initiating cells directly beneath the inactive center of the apex.

The organizational concepts of Hanstein and Haberlandt are represented by figure 4. The corresponding regions can be observed in the soybean root apex as shown in figure 5. While either set of names could be applied to the regions observed in the soybean root, the mere coincidence of patterns does not preclude other more plausable and satisfactory explanations of organization.

In the soybean apex there is no evidence for a single apical cell or two or three apical initials as proposed by Guttenberg for dicotyledons (fig. 3).

The quiescent center as diagramed in figure 1 approaches most closely the organization of the soybean root apex. While this study has failed to define a minimal constructional area, observations of longitudinal and transverse sections of the soybean root apex show evidence of the presence of a quiescent center.

Further study is being conducted concerning the organization of the soybean root apex. It appears that no present theory on root apices is wholly acceptable. Esau (8) and Popham (18), studying pear and pea roots, found that organization varies some with the age of the root. For example in pea the tissue in the 5 day old root matured more slowly than in the 20 day old root. This change in rate of maturation means that mature tissues are found closer to the initiating cells in the older plants. With variation like this within species it is not unreasonable to expect differences between species.

Literature Cited

1. BRUMFIELD, R. T. 1943. Cell-lineage studies in root meristems by means of chromosome rearrangements induced by X-rays. Amer. Jour. Bot. **30** : 101-110.
2. CLOWES, F. A. L. 1959. Reorganization of root apices after irradiation. Ann. Bot. **23** : 205-210.
3. CLOWES, F. A. L. 1956. Nucleic acids in root apical meristems of *Zea*. New Phyto. **55** : 29-34.
4. CLOWES, F. A. L. 1956. Localization of nucleic acid synthesis in root meristems. Jour. Expt. Bot. **7** : 307-312.
5. CLOWES, F. A. L. 1958. Protein synthesis in root meristems. Jour. Expt. Bot. **9** : 229-238.
6. CLOWES, F. A. L. 1958. Development of quiescent centres in root meristems. New Phyto. **57** : 85-88.
7. ESAU, K. 1953. Plant Anatomy. John Wiley and Sons, Inc. New York. pp. 92-122.
8. ESAU, K. 1943. Vascular differentiation in the pear root. Hilgardia **15** : 299-324.
9. FOSTER, A. S. 1949. Practical Plant Anatomy. 2nd ed. D. Van Nostrand Company, New York.
10. GUTTENBERG, H. VON. 1947. Stubien uber die Entwicklung des Wurzelvegelationspunktes der Dikolyledonen. Planta **35** : 360-396.
11. HANSTEIN, J. 1868. Die Scheitelzellgruppe im Vegetationspunkt der Phanerogamen. Festschr. Niederrhein. Gesell. Natur-und Heildunde 109-134.

12. HANSTEIN, J. 1870. Die Entwicklung des Keimes der Monokotylen und der Dikotylen. Bot. Abhandl. **1**(1) : 1-112.

13. HABERLANDT, G. 1914. Physiological Plant Anatomy. Macmillan and Company. London.

14. JENSEN, W. A. and KAVAJIAN, A. G. 1958. An analysis of cell morphology and the periodicity of division in the root tip of *Allium cepa*. Amer. Jour. Bot. **45** : 364-372.

15. MANN, L. K. 1952. Anatomy of the garlic bulb and factors affecting bulb development. Hilgardia **21** : 195-251.

16. MILLER, R. H. 1958. Morphology of *Humulus lupulus* 1. Developmental anatomy of the primary root. Amer. Jour. Bot. **45** : 418-431.

17. POPHAM, R. A. 1955. Tissue differentation in *Pisum* roots. Amer. Jour. Bot. **42** : 529.

The Maturation of the Trifoliate Leaf of *Glycine max*

R. D. Decker and S. N. Postlethwait, Purdue University

Introduction

The morphogenesis of the trifoliate leaf of the soybean, *Glycine max*, var. Hawkeye, can be divided into two phases. The first phase is the formation of six layers of histogenic initials and the second is the maturation of these layers into fully developed leaves. As the first phase is still under study, this paper deals with the latter.

Materials and Methods

The material used for sectioning was grown in the greenhouse at Purdue University during the summer of 1959. Collections were made from the first and second trifoliate leaves every other day during their growth from one centimeter in length at the midrib to maturity. Randolph's Modified Navashin Fluid (CRAF) was used as the killing and fixing agent. Following dehydration in ethyl alcohol, the material was embedded in tissuemat, sectioned at 10μ, and stained with chlorazol Black E.

Results

Thirteen days after planting the first trifoliate leaf has developed to a size large enough to handle as a separate unit. At this time the leaflets are still folded and the tissue of the lamina is undifferentiated. A cross section through the lamina of one of the lateral leaflets displays six layers or rows of histogenic initials (Fig. 1).

The two outer layers of cells form the epidermis. The upper layer forms the adaxial epidermis and the lower layer forms the abaxial epidermis. The cells of the epidermis are the first to cease cell division. However, these cells have the longest and greatest period of enlargement (1). At this stage of development these cells are isodiametric. Numerous epidermal hairs are present.

The two layers of cells adjacent to the abaxial epidermis form the spongy mesophyll. With only a few exceptions cell divisions stop in this

---

Plate 1.

Figure 1. A cross section of a leaflet of a second trifoliate leaf showing the six layers of the young meristematic cells. The leaflet measured approximately one centimeter long at the midrib. (141X)

Figure 2. A cross section of a leaflet of a first trifoliate leaf exhibiting partial differentiation. The epidermis and spongy mesophyll tissue are expanding while the palisade tissue is still somewhat meristematic. The leaflet measured approximately 2-3 centimeters long at the midrib. (188X)

Figure 3. A cross section of a leaflet of a second trifoliate leaf fully mature. Cell division and expansion have stopped and the intercellular spaces have been formed. The leaflet measured approximately 5-6 centimeters long at the midrib. (188X)

Figure 4. A cross section of the mature petiole of the second trifoliate leaf near the base of the lamina. There is an epidermis, ground parenchyma region, and vascular cylinder present. (150X)

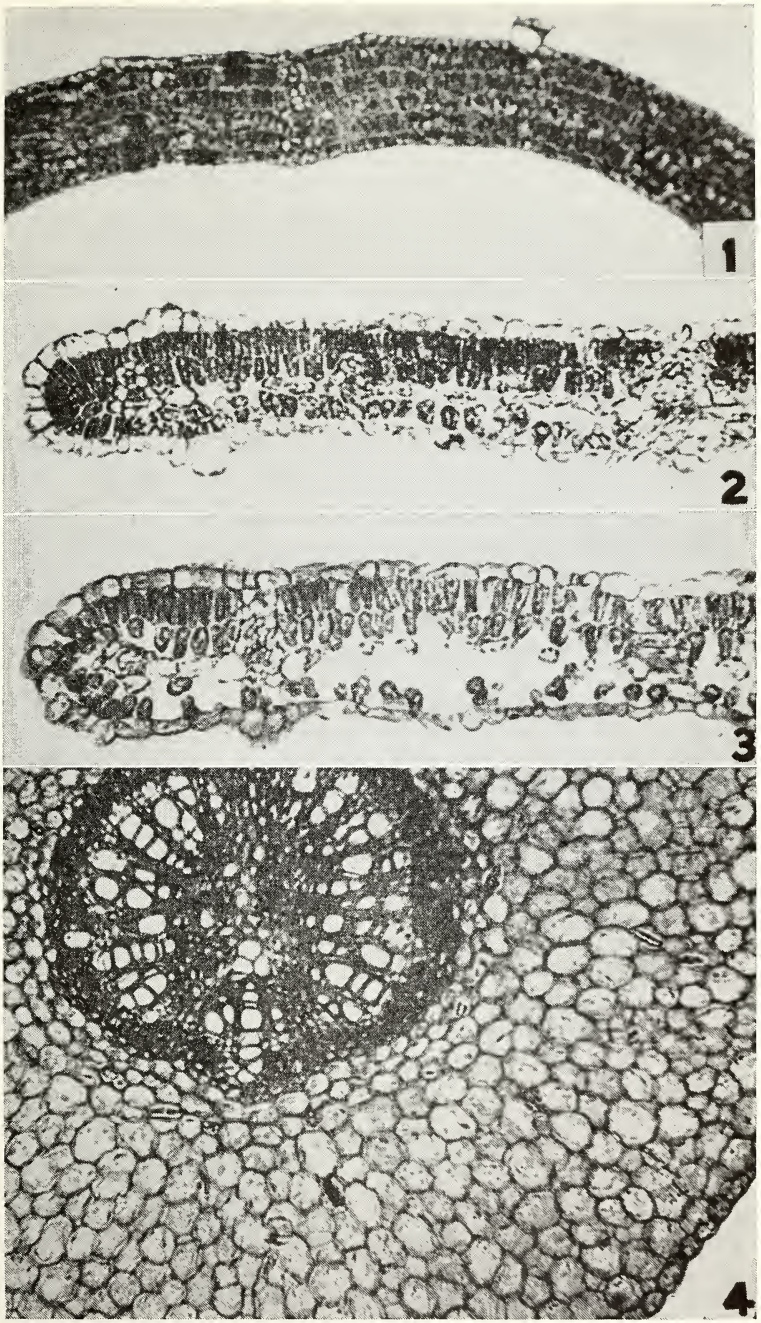


Plate 1

region very soon after the epidermis ceases dividing. Avery (1), in his study on the tobacco leaf, accounts for the large intercellular spaces of the mature spongy mesophyll by the fact that the abaxial epidermis and the spongy mesophyll stop cell division at approximately the same time, and that the epidermis has the greater expansion period. The leaf of the soybean develops in a similar manner.

The remaining two layers form the two layers of palisade tissue. Active cell division continues in this tissue longest. The intercellular spaces are small in contrast to the intercellular spaces in the spongy mesophyll tissue because the palisade cells are still dividing during most of the period of epidermal expansion.

In the intermediate stage of maturation, the upper and lower epidermis and the spongy mesophyll have stopped cell division and begun to enlarge and differentiate (Fig. 2). The palisade layers continue to divide with only a slight amount of differentiation evident. Intercellular spaces are visible in the spongy mesophyll but not in the palisade region.

The abaxial and adaxial epidermal layers form a continuous layer over the margin in the fully mature leaf (Fig. 3). The palisade layer extends around the margin, and has some intercellular spaces. Often the cells of the inner palisade layer are forked while cells of the outer layer remain unforked. The spongy mesophyll layer develops extensive intercellular spaces when its cells reach maximum size. Due to the expansion of the epidermis, the palisade cells with their darkly stained chloroplasts, lose some of the regular arrangement they possessed as undifferentiated cells (Fig. 5). The network arrangement of the spongy mesophyll cells is clearly visible. As previously mentioned, the palisade cells are the last cells of the leaf to cease cell division with only a few exceptions. The vascular endings in the spongy mesophyll layers can be seen in figure 6. Some of the young mesophyll cells remain meristematic and become provascular tissue as the lamina expands (1). The pathway of materials to and from the cells of the lamina can be seen clearly (3).

In the young midrib, a cambium-like region is visible which gives rise to the newly formed xylem and phloem (Fig. 7). Both protophloem and metaphloem are present. There is also some internal phloem present. The crushed protoxylem can be seen along with with the developing metaxylem. Some of the metaxylem cells still contain the cell contents yet show definite secondary wall thickening. In the more fully developed midrib (Fig. 8), the cambium-like region is less distinct due to maturation. The mature xylem and phloem are located in the characteristic arrangement

---

Plate 2.

Figure 5. A peridermal section through the palisade tissue of the fully matured leaflet of a second trifoliate leaf. Also shown is the vascular pattern and some spongy mesophyll tissue. The leaflet measured approximately 5-6 centimeters long at the midrib (127X)

Figure 6. A peridermal section through the spongy mesophyll tissue of the fully matured leaflet of a second trifoliate leaf. The vascular endings and their connection to the spongy mesophyll tissue are clearly visable. The leaflet measured approximately 5-6 centimeters long at the midrib. (114X)

Plate 2

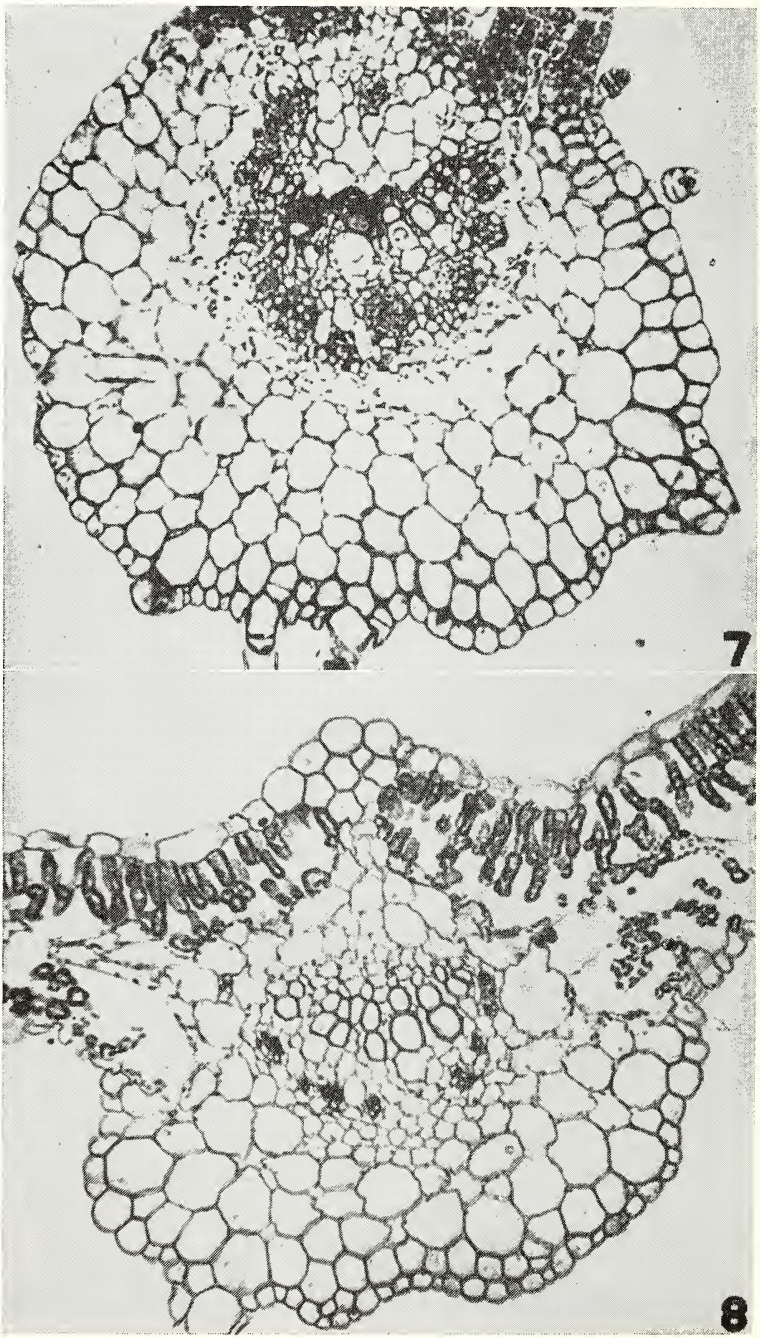


Plate 3

with the phloem occurring in small patches of darkly stained cells on the abaxial side of the xylem.

The epidermis of the mature petiole is pubescent as is the leaf and stem. There is a layer of ground parenchyma (2) or cortical tissue (3) which surrounds the vascular system. The center is occupied by crushed xylem and no pith is present (Fig. 4). Large xylem elements are maturing which suggest the presence of a cambium or cambium-like region. The phloem is oriented towards the periphery of the petiole encircling the xylem (2).

Discussion

Mounts (4) showed one layer of palisade tissue and three layers of mesophyll tissue in *Vitis* and *Catalpa* leaves. The *Malus* leaf is eight to ten layers of cells in thickness; one to three layers being palisade, two forming the epidermis, and the remaining layers forming the mesophyll tissue (3). The tobacco leaf is described as having an upper and lower epidermis, an upper mesophyll which develops into the single palisade layer, a middle mesophyll, and lower mesophyll. The latter two form the spongy mesophyll (1). The soybean is found to possess two outer layers which form the epidermis, two layers which form the palisade tissue, and two layers which form the spongy mesophyll. Avery (1) and MacDaniels and Cowart (3) indicate that whatever the number of layers of cells a leaf primordium may have, this number generally remains constant throughout the life of the leaf. All authors cited and the writers agree that the number of layers of cells of leaf primoidia vary slightly. The sequence of cessation of cell division of the various layers in all the species discussed is essentially the same.

Esau (2), citing the work of Sharman 1942 as an example, indicates that the vascular differentiation of the midrib is acropetal while the small veinlets (Figs. 1, 2, 3) differentiate in a basipetal direction. The vascular development of the soybean follows this pattern.

Once the number of layers of cells of the leaf primordium is established, the soybean leaflets follow the same pattern of differentiation and maturation as that found for other species described by Mounts (4), MacDaniels and Cowart (3), and Avery (1).

Summary

The differentiation and maturation of the trifoliate leaf of *Glycine max* follows a basipetal pattern for the veinlets of the leaf tissue while the midrib is acropetal. Six layers of undifferentiated cells are formed in the lamina. This number is constant throughout the life of the leaf. The two outer layers form the epidermis. The two layers beneath the upper

---

Plate 3.

Figure 7. A cross section through the midrib of the young second trifoliate leaf. This shows the epidermis, ground parenchyma, and developing vascular tissue. The leaflet measured approximately one centimeter at the midrib. (229X)

Figure 8. A cross section through the midrib of the mature first trifoliate leaf. Secondary xylem form rows while secondray phloem is collected in small groups. The leaflet measured approximately 5-6 centimeters at the midrib (194X)

epidermis form the palisade tissue and the two layers above the lower epidermis form the spongy mesophyll tissue. The differentiation and maturation pattern for the leaflets of this trifoliate leaf are similar to that of a simple leaf.

Literature Cited

1. AVERY, G. S. Jr. 1933. Structure and development of the tobacco leaf. Amer. Jour. Bot. **20** : 565-592.
2. ESAU, KATHERINE, 1953. Plant Anatomy. John Wiley and Sons, Inc., New York.
3. MACDANIELS, L. H. and COWART, F. F. 1944. The development and structure of the apple leaf. New York Cornell Agri. Exp. Sta. Memoirs **258** : 1-29.
4. MOUNTS, B. T. 1932. The development of foliage leaves. Univ. of Iowa Studies Natural History. **14**(5) : 1-19.

A Preliminary Morphological Study of *Epifagus virginiana* (L.) Bart.

A. E. Brooks, Wabash College[1]

A parasitic plant common to the Eastern United States is *Epifagus virginiana* (L.) Bart. Linnaeus first described it under the name of *Orobanche virginiana* in 1753. Dr. Herman Schrenck (6) made the first detailed study of *Epifagus* in 1894. His work was physiological in nature, being concerned with the parasitism of the plant, although some emphasis was given to the anatomy and general morphology. In 1895, Dr. Macfarlane, of the University of Pennsylvania, began a study of *Epifagus* which was completed by Ethel Cooke and Adeline F. Schively (2) in 1904. Their work dealt with the general structure of the plant, emphasizing the organization and development of the flower. The most recent study of the Orobanchaceae of which *Epifagus* is a genus was conducted in 1920 by Irwin Boeshore (1). He presented an account of the general morphology and histology of the root, along with a comparative study of the stem, leaf, and flower parts including the nectaries and seeds of other species of the Orobanchaceae and the semiparasitic Scrophulariaceae. With the information presented in the aforementioned papers in mind, it is the aim of this author to contribute to the general knowledge of the morphology, especially the anatomy, of this common woodland plant.

Most of the plants used in this study were collected in the W. C. Allee Memorial Woods, Parke County, Indiana. A few very young developmental stages were collected at Ringwood near Ithaca, New York. *Epifagus* can usually be found growing in the thick duff at the base of, or in the near proximity of, *Fagus grandifolia*. Some specimens, however, have been found quite distant from beech trees and on slopes where a duff was absent. All specimens were preserved in FAA immediately after collection, and then sectioned and stained, using Safranin O and Fast Green, according to standard methods of plant microtechnique (3).

At maturity, the branched plant ranges from twelve to eighteen inches in height, and usually appears inconspicuously light brown in color. In some areas the abaxial surface of the lateral branches is a dull purple in color indicating a concentration of anthocyanin. Pease (5) reported a form which was, except for the corolla, purple throughout, while Palmer (4) reported a population in which the individuals were butter yellow in color. These forms are evidently the exceptions and are not consistent with those plants collected by the author.

The leaves of *Epifagus* are reduced to small tooth shaped scales arranged in a 2/5 phyllotaxy about the aerial portion of the main axis. Stomata are present on the scales, and multicellular hairs are borne along the edges of the scales, but neither are numerous.

By digging within the duff in late August, beneath plants of the previous year, it is possible to find young plants in various stages of

1. The author is indebted to the National Science Foundation which made this study possible through an Undergraduate Research grant; to Dr. C. F. Shutts for his assistance with the photomicrographs; and especially to Dr. R. A. Laubengayer for his innumerable suggestions.

development. These younger forms have an enlarged basal portion which at maturity is the subterranean tuber. On the enlarged portion of many, fragments of beech root are often evident. At this young stage, the plants are commonly white to butter yellow in color, and may range in size from one millimeter to several centimeters.

A study of sections through the tip of the stem shows that groups of apical and subapical cells constitute the initiating body of the stem. The initials appear to be in three tiers, the cells of the outer one dividing anticlinically and those of the inner ones dividing in all planes.

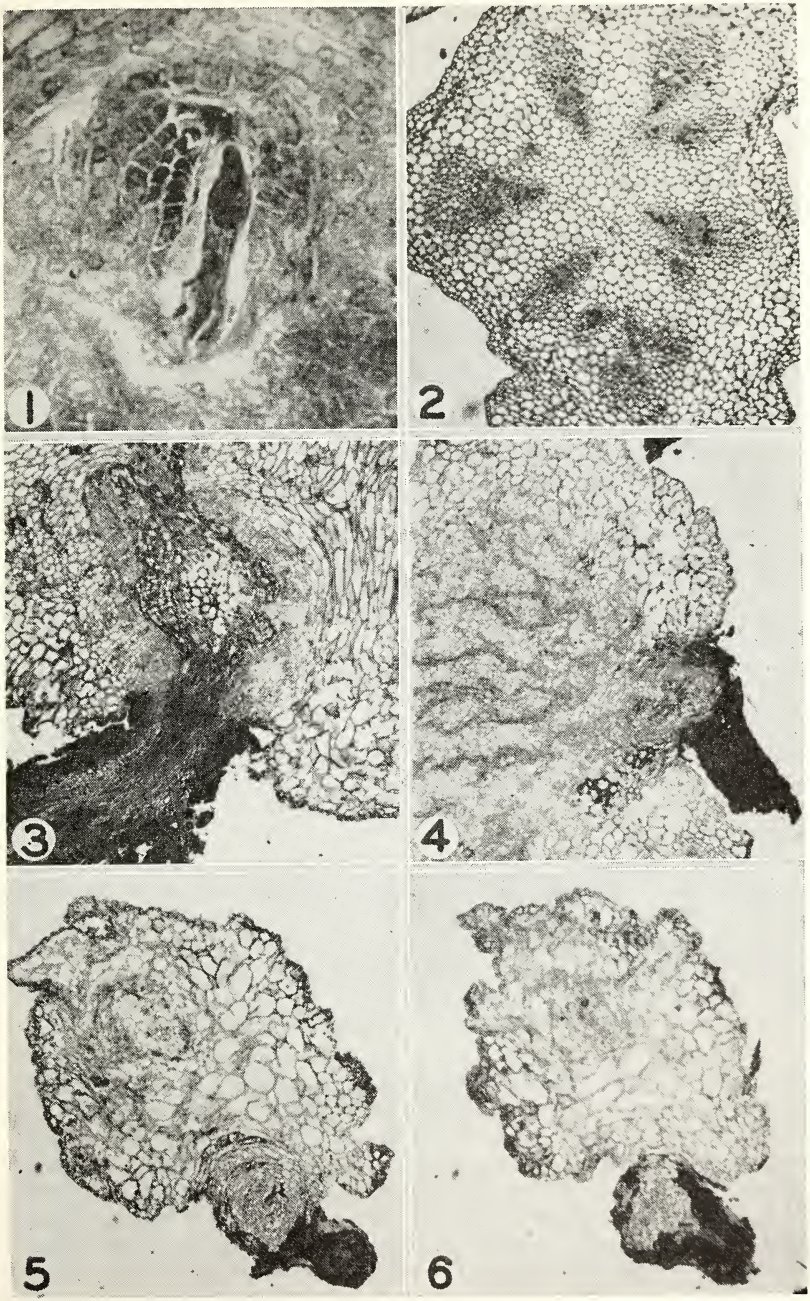
Cross sections of the stem reveal an internal anatomy common to most herbaceous dicotyledons. A relatively thick waxy cuticle appears to envelop the epidermis of the stem. The regular epidermis is composed of narrow cubical cells; stomata and multicellular trichomes appear at infrequent intervals along the stem. Large, elongate parenchyma cells with numerous intercellular spaces make up the relatively narrow cortical region of the stem. These cells are usually devoid of starch grains at maturity.

Contrary to what was reported by Cooke and Schively (2) and by Boeshore (1), this worker found the vascular system to consist of a definite ring of bundles (Fig. 2), not scattered bundles as was previously reported. It is a dictyostele made up of bicollateral bundles since a small amount of internal phloem has been detected in most sections. The number of bundles in the mature stem usually ranges somewhere between nine and thirty. Each bundle is capped by a mass of sclerenchyma cells, fibers, toward the outside of the axis. The phloem accounts for about one third the size of each bundle. Since a defined pericycle and endodermis as well, are absent, the outer portions of the bundle caps could be considered a pericyclic region. There appears to be no evidence to indicate the presence of a vascular cambium and hence all growth is primary.

The phloem consists of sieve tube elements and companion cells, and exceeds the xylem in mass to a greater or lesser extent. Boeshore (1) considered this reduction in the amount of xylem a further advance in degradation which accompanies an increased parasitic habit. Compound sieve plates have been observed on the oblique end walls of the sieve tube elements. The cells of the phloem are relatively small, and angular in cross section, although a few large spherical cells have been spotted in this region. These cells appear to be phloem parenchyma. This author is in disagreement with Cooke and Schively (2), as well as Boeshore (1), who report, "an internal phloem is almost always present, often in excess of the outer phloem mass." In many sections, including those of various developmental stages, through a great number of locations along the axis,

---

Fig. 1-6 *Epifagus virginiana* (L.) Bart. Fig. 1.—Longitudinal section through ovule showing microphylar haustorial endosperm. x43. Fig. 2.—Cross section of mature stem showing ring of bicollateral bundles. x5. Fig. 3—Longitudinal section of older tuber showing region of attachment with *Fagus grandifolia*. x5. Fig. 4.—Longitudinal section of young tuber showing haustorium penetrating beech root and converging xylem masses. x10. Fig. 5.—Longitudinal section of young plant showing a well differentiated haustorium and beech root in cross section. x10. Fig. 6.—Longitudinal section showing same features as fig. 5. x10.


1
2
3
4
5
6

the internal phloem never exceeds the outer phloem in mass and in fact is always present in very small amounts. The internal phloem is at times, depending on the age and location along the axis, almost indistinguishable from the cells of the outer pith. The structure and cell type of the inner phloem mass is similar to that of the external phloem.

The xylem is composed of tracheids, mainly scalariform pitted, and vessels. The length of the vessels greatly exceeds that of the tracheids, and they show a porous end wall condition as well as annular, loosely spiraled, tightly spiraled, and scalariform elements, indicating protoxylem and rapid growth. The protoxylem elements appear consistently nearer the center of the axis, and this establishes an endarch arrangement and centrifugal development. The xylem of the mature stem is easily recognized by the thick walls of its cells and usually consists of two or three cell rows. These cells are much larger than those of the phloem, and nearly as large as those composing the bundle caps in size and shape, when seen in cross section.

Occupying the center of the axis are the large elongate parenchyma cells of the pith. Similar to the cortical region, many intercellular spaces are present in the pith. The cells of this group are commonly larger than the cortical parenchyma, often reaching their greatest size in the pith rays which extend outward to the cortex, between the vascular bundles. Unlike the cortical cells, the cells of the pith usually contain numerous starch grains. The quantity of starch decreases in the pith ray cells from the pith to the cortex.

The tuber, from which the erect stem arises, consists of an elongated subterranean structure ranging between one and four centimeters in length. It is covered with numerous small stiff branched structures. Schrenk (6) referred to these structures as grapplers. This underground structure seems to be similar to the Irish potato tuber. Boeshore (1) looked upon the tuber as a fused primary root below and a greatly condensed vegetative stem-axis above. A section through the tuber reveals an anatomy somewhat different from the arrangement found in the stem. A single layered epidermis very similar to that of the stem forms the outer covering of the tuber. Just beneath the epidermis is a narrow band of parenchyma cells corresponding to the cortical cells of the stem. In the center of the tuber are larger parenchyma cells like those of the stem pith. Unlike the condition found in the erect stem, starch grains are uniformly present in all but the vascular cells of the tuber.

Although there is a similarity of cell type between the phloem of the stem and that of the tuber, the phloem in the tuber follows a very irregular branching pattern. In both cross and longitudinal sections it appears not to be closely associated with the xylem. The xylem masses in the tuber are arranged in a ring, like the bundles in the stem. Each of these masses appears to converge toward the point of attachment with the beech root. Just within the *Epifagus* tuber near the point of attachment with the host, the xylem appears as a single large mass. The xylem masses present in the tuber, but distant from the point of attachment, are rarely more than four or five cells in width and are usually cubical reticulate tracheids. Bundle caps, when present, are always smaller in mass than those present in the stem.

The actual root or grappler is a short stiff branched structure at maturity and is supplied with a single mass of vascular tissue, which seems to represent a stele. The xylem of this mass rarely consists of more than a single row of tracheid, which suggests a diarch arrangement. Each root arises in the pericyclic region of the tuber and forces its way outward through the cortex and epidermis. Although these structures lack root caps, they possess other characters which strongly suggest that they are true roots. This worker has no basis to disagree with Boeshore (1) who reports that these structures are functionless due to the high degree of parasitism exhibited by *Epifagus*.

Although many specimens that were collected appeared to be growing independent of the beech, all showed a definite attachment to the beech root when examined microscopically, regardless of age. In older stages of *Epifagus*, the beech root appears deeply or shallowly buried within the tuber, as has been reported by previous workers (1) (2). The author agrees with Boeshore who suggested that this condition arises by the development of the tuber tissues around the beech root, eventually both becoming confluent; but there is disagreement as to when the actual connection has been established. Boeshore contended that the connection is established when the *Epifagus* tuber has partially or totally enveloped the beech root. This suggests that there is a time during the young developmental stages of *Epifagus* when it lives independently. More conclusive evidence has been found by sectioning very young forms of *Epifagus*.

These sections reveal that a definite hastorium is formed within the parasite (Figs. 4, 5 & 6). It develops outward and pierces the small beech root thus establishing the union between host and parasite at a very early stage in the development of the latter. This haustorium-like organ has not been reported by any of the past workers. As the tuber develops around the beech root the haustorium becomes less and less evident. (Figs. 4, 5 & 6). At maturity the haustorium of *Epifagus*, in most cases, is not evident (Fig. 3).

The inflorescence of *Epifagus*, formed at maturity, is a spike, in which the upper flowers are sterile. Each of the lower fertile flowers contains four stamens and a pistil. The style is relatively short and merges with a large globose ovary. The ovary and style are glabrous and the stigma shows a much branched condition. The numerous ovules within the ovary, which is composed of four fused carpels, show a shallow axile placentation. Enclosing the pistil and stamens are the modified corolla and calyx which resemble the rest of the plant in color. The flower is undoubtedly a cleistogamous one with self-pollination occurring.

Shortly after fertilization a micropylar haustorial endosperm is evident (Fig. 1) and it later develops into the cellular endosperm of the seed. The fertilized egg undergoes divisions forming a several celled undifferentiated embryo at the time of seed shedding in the late fall. The integuments undergo modification forming a tough, heavily lignified, ridged seed coat. The seeds are elongate and quite small, less than one half a millimeter in length. Cooke and Schively reported that between 700 and 1800 seeds are formed by the plants. (2)

After examination of soil samples collected beneath dead plants of the previous growing season, many seeds shed the past year were obtained.

Sections of these seeds revealed an internal condition very different from that present at the time of shedding. The embryo had become differentiated into a many celled body which was enlarged at one end and tapered abruptly into a nearly filamentous structure at the opposite end. The cells of the endosperm had also become modified, containing irregular masses of granules. These aggregations of granules seem to represent some sort of stored food. The condition of the embryo of *Epifagus* indicates that it undergoes a development similar to the embryos of many kinds of orchids. Differentiation does not occur until the seeds have been shed and have passed through a period of dormancy.

There are many phases of the life cycle of *Epifagus* which have not been thoroughly investigated, especially those stages between fertilization and germination. In spite of the fact that there are several points of difference between the results presented here and previous investigations, it can be concluded that the general morphology indicates, without question, that *Epifagus virginiana* is truly a parasitic plant.

Literature Cited

1. BOESHORE, IRWIN. "The Morphological Continuity of Scrophulariaceae and Orobanchaceae." Contributions from the Botany Laboratory of the University of Pennsylvania, 5 : 139-177 Pl. 12-16. 1920.
2. COOKE, ETHEL and ADELINE F. SCHIVELY. "Observations on the structure and Development of *Epifagus virginiana*." Contributions from Botany Laboratory of the University of Pennsylvania II. No. I., 1904.
3. JOHANSEN, DONALD. *Plant Microtechnique*—McGraw-Hill Book Co. 1940, New York.
4. PALMER, S. C. *"Epifagus virginiana."* Rhodora **57**(674) : 71-72, 1955.
5. PEASE, ARTHUR STANLEY. "A color Form of Beechdrops." Rhodora **54**(641) 140, 1952.
6. SCHRENK, HERMAN. "Parasitism of *Epifagus virginiana*." Proceedings of the American Microscopical Society. Jan. 1894, Part II.

Peroxidase Distribution in Geotropically Stimulated Candles of *Pinus strobus* L.[1]

Arthur H. Westing, Purdue University

The peroxidases are a class of enzymes capable of oxidizing a wide variety of substrates in the presence of peroxide. The results of several investigations (1, 2, 3, 4) suggest that the peroxidases are not only involved in regulating the level of auxin activity in a plant but that their own level is in turn influenced by the amount of auxin present.

A geotropic response is a directed, i.e., an oriented growth response in which the required orientation for the plant is provided by the direction of the force of gravity. There is much evidence to support the supposition that a geotropically stimulated organ tends to right itself by developing a transverse asymmetry of auxin distribution. It was therefore thought desirable to investigate the peroxidase distribution following geotropic stimulation.

As an exploratory step, a limited group of terminal candle clusters (averaging five candles per cluster) was collected from eastern white pine (*Pinus strobus* L.) wildings six to eight years old and ninety to one hundred centimeters tall. The terminal bud clusters had begun to expand about a month before and at the time of collection the shoots averaged twelve centimeters in length, or roughly a quarter of their expected total growth. Leaders and laterals were at this time still indistinguishable in gravitational response, both being strongly negatively geotropic.

Candles of trees bent to the horizontal at this early stage in the growing season exhibit remarkably rapid recovery. Thus the apical half of a candle was found to right itself completely within two days or so (producing an "L" shape). Asymmetric growth actually continues for a short period; the resulting over-recovery is in turn corrected. Recovery is primarily brought about by asymmetric growth in the longitudinally central portion of the candle, the region of most active cell elongation at this time of the growing season.

Candles were collected from trees which had been inclined to the horizontal for two days as well as from untreated, vertical control trees. The candles were frozen immediately upon collection and stored in this condition. The bracts or immature fascicles were removed prior to testing.

The candles were homogenized in one-tenth molar monobasic potassium phosphate and the insoluble matter discarded. Owing to their small size two or three candles from one cluster were pooled for the preparation of a single extract. Extracts were tested for their peroxidase activity by an assay modified from that of Sharpensteen et al. (6). It is based on the ability of peroxidases to combine with hydrogen peroxide and then to oxidize the colorless compound pyrogallol to a stable yellow compound,

1. This article is based on a portion of a dissertation presented for the degree of Doctor of Philosophy in Yale University. The author is indebted to Arthur W. Galston, Yale University and Delbert C. McCune, Boyce Thompson Institute for Plant Research for guidance and advice.

presumably purpurogallin. The rate at which the purpurogallin forms is determined colorimetrically and taken as a measure of the peroxidase activity. Dialysis against one-tenth molar monobasic potassium phosphate (1:500) increased the peroxidase activity of an extract about twenty percent, but was not adopted as a standard procedure because the increase was similar for any extract. The data are presented in relative terms since details of assay technique were changed several times.

Longitudinal distribution of peroxidase activity was determined by cutting the candles into four equally long segments and preparing extracts based on fresh weight from each part. The results of this investigation are presented in Table 1. The data reveal a basipetally increasing gradient of peroxidase activity in the expanding candles. Roughly one-tenth of the total activity is found in the apical quarter of the candle and this increases to roughly one-half in the basal quarter. The gradient thus appears independent of the central region of early elongation, seeming rather to be proportional in magnitude to the distance from the apical meristem. The limited data in the lower portion of Table 1 indicate, moreover, that this distribution is essentially the same in candles inclined for two days as in the erect candles. The gradient for peroxidase activity described here for the candles of eastern white pine is thus similar to the one described by Mirov (5) for the overall auxin activity of the diffusates of candles obtained from ponderosa (*P. ponderosa* Laws.) and Torrey (*P. torreyana* Parry) pine seedlings.

Transverse distribution of peroxidase activity was determined by splitting several candles longitudinally into upper and lower halves. Owing to limited plant material, data for this phase of the investigation are available only for the basal half (i.e., the third and basal quarters), of several candles. The basal half of the candle did, however, receive maximum geotropic stimulation during the treatment since it remained relatively horizontal during this time. This region, furthermore, exhibits most of the peroxidase activity found in a candle. The results of this phase of the study are summarized in Table 2. It is seen that horizontal displacement of the candles resulted in a nonsymmetrical distribution of peroxidase activity with as much as three-fifths of the total activity of a segment being found in its lower horizontal half.

The preliminary findings reported here, therefore, suggest that a correlation exists between the enzyme peroxidase and a geotropic stimulation. A detailed kinetic investigation of the relationship between auxin and peroxidase activities in the upper and lower halves of geotropically stimulated organs would perhaps indicate whether a peroxidase redistribution is responsible for the auxin redistribution found in organs so stimulated. The many candles of a single pine are well suited for such a study.

Summary

Elongating candles of *Pinus strobus* L. were discovered to possess a basipetally increasing gradient of peroxidase activity. This longitudinal gradient appeared to be independent of candle orientation. Inclination of candles did, however, result in a transverse asymmetry with the lower horizontal side of the candle developing the greater peroxidase activity.

Table 1. Longitudinal Distribution of Peroxidase Activity in Erect Candles of *Pinus strobus* L. and in Candles Inclined for Two Days.

	Peroxidase Activity in Segment as a Percentage of Activity in Entire Candle			
Position of Candle	Apical Quarter	Second Quarter	Third Quarter	Basal Quarter
Erect	9	27	22	42
Erect	19	17	32	32
Erect	20	15	30	35
Erect	4	8	22	66
Erect	6	4	15	75
Erect Average	*11.6*	*14.2*	*24.2*	*50.0*
Inclined	12	16	23	49
Inclined	10	11	24	55
Inclined Average	*11.0*	*13.5*	*23.5*	*52.0*

Note: Two candles were pooled for the preparation of each extract.

Table 2. Transverse Distribution of Peroxidase Activity in the Basal Half of Candles of *Pinus strobus* L. Inclined for Two Days.

Peroxidase Activity in Segment (% Upper Horizontal Half / % Lower Horizontal Half)	
Third Quarter	Basal Quarter
42/58	46/54
40/60	49/51
42/58	45/55
38/62	43/57
Average	
40.5/59.5	*45.8/54.2*

Note: Three candles were pooled for the preparation of the first two extracts and two for the last two.

Literature Cited

1. GALSTON, A. W., J. BONNER, and R. S. BAKER. 1953. Flavoprotein and peroxidase as components of the indoleacetic acid oxidase system of peas. Arch. Biochem. **42**: 456-470.
2. GALSTON, A. W. and L. Y. DALBERG. 1954. Adaptive formation and physiological significance of indoleacetic acid oxidase. Amer. Jour. Bot. **41**:373-380.
3. GOLDACRE, P. L. 1951. Hydrogen peroxide in the enzymic oxidation of heteroauxin. Aust. Jour. Sci. Res. Sect. B [now Aust. Jour. Biol. Res.] **4**:293-302.
4. JENSEN, W. A. 1955. Histochemical localization of peroxidase in roots and its induction by indoleacetic acid. Plant Physiol. **30**:426-432.
5. MIROV, N. T. 1941. Distribution of growth hormone in shoots of two species of pine. Jour. Forest. **39**:457-464.
6. SHARPENSTEEN, H. H., A. W. GALSTON, and S. M. SIEGEL. 1956. Spontaneous inactivation of pea root peroxidase and its acceleration by coenzyme A. Physiol. Plant., Copenhagen **9**:363-369.

Antibiotic Substances from *Ranunculaceae*

Sister Marie Bernard, O.S.F., Mary Jo Metzger, Marian College

It has been known for quite some time that extracts of many species of the family *Ranunculaceae* exert an inhibitory effect on the growth of a wide variety of microorganisms including bacteria, fungi, yeasts, and protozoa. The literature on this seems to be somewhat inconsistent. It was partly because of this that the present investigation was undertaken and partly through the interest of the Indiana State Board of Health to find a substance which would inhibit the growth of *Candida albicans* but not that of other organisms commonly found growing together with it.

The antibiotic substance present in the flowers, stems, and leaves is a lactone, protoanemonin, which on exposure to air polymerizes to form anemonin, which also possesses antibiotic properties, although to a lesser degree.

The first known work on the antibacterial action of *Ranunculaceae* was done sometime prior to 1850 by Clarus (5). Erdmann in 1858 (5) suggested that a certain volatile oil present in these plants caused their sharp odor, and that this oil could easily be converted to two other substances which he called anemonin and anemonic acid. Two Japanese chemists Asahina and Fujita (5) have given us the structure for protoanemonin and anemonin and have synthesized protoanemonin.

The antibacterial action of these extracts was first described by Boas (1) in 1934. The most extensive study was made by Holden, Seegal and Baer (4) in which extracts of *Ranunculus* and *Anemone pulsatilla* were found to exert an inhibitory action on the growth of a number of pathogenic bacteria, fungi, and protozoa.

Plants were collected in early October and stored for a few days at a temperature of approximately 35°F. Four different extracts were prepared and tested. The extract, termed "juice", was obtained by putting the stems and leaves of plants through a meat grinder. The resulting material was mixed thoroughly with an equal amount, by weight, of distilled water. The mixture was then pressed through gauze, sterilized and stored at 35°F. From this was prepared a second extract, the "distillate", by steam distillation of part of the juice. From the distillate the two other extracts—protoanemonin and anemonin were finally obtained after a method described by Boas and Steude (2) in which a portion of the distillate was saturated with NaCl; an equal volume of ether was added and the mixture shaken thoroughly in a separatory funnel. The ether layer, containing the antibiotic substance, was drawn off, and measured portions placed in sterile petri dishes. The ether evaporated from these leaving behind the protoanemonin to which was immediately added glucose agar and the two then thoroughly mixed. Portions of the ether mixture were placed in other petri dishes and the ether allowed to evaporate. The protoanemonin thus obtained was left exposed to the air at room temperature for about two hours; during this time the protoanemonin polymerized to form anemonin. Glucose agar was then added to the plates and mixed with the anemonin. Also present

with the anemonin was a whitish substance which possibly corresponded to the isoanemonin acid described by Boas and Steude (2).

The four extracts just described—juice, distillate, protoanemonin, and anemonin, were tested for their antibiotic effects on *Candida albicans*, a species of *Penicillium*, *Rhizopus nigricans*, *Staphylococcus aureus*, *Bacillus megaterium*, *Aerobacter aerogenes*, *Sarcina lutea*, and *Mycobacterium smegmatis*. The yeast and two molds were subcultured in the agar, the bacteria were streaked on the plates. Tests were run a minimum of five times along with proper controls. All organisms were incubated for at least one week.

Amounts from 0.1 to 1.0 cc. of the juice and distillate were used. The concentrations of protoanemonin and anemonin were determined by measuring the amount of antibiotic-containing ether placed in the petri dishes, assuming that all went into solution in the ether. Both substances are very soluble in ether but only slightly so in water.

It was found that the juice was potent for about ten months. The distillate was perfectly clear and colorless and could only be recognized by the characteristic odor of the juice. The distillate was kept under the same conditions as the juice and was effective for about six months. The protoanemonin was a pale-yellow oil having a strong, putrid odor which was somewhat irritating. The anemonin was crystalline in form and odorless.

The effects of juice and distillate were studied more thoroughly on *C. albicans*, *Penicillium*, and *R. nigricans*. Both extracts were used over a period of ten months but their power of inhibition seemed to decline from month to month. Complete inhibition of the growth of *C. albicans* was obtained with as little as 0.1 cc. of freshly prepared juice. The same was true for the distillate. However, after ten days a slight amount of growth appeared on plates containing 0.10 cc. but not those containing 0.15 cc. distillate. After two weeks incubation these latter showed no growth.

When tests were run using juice and distillate, each four months old, a minimum of 0.20 cc. of juice inhibited *C. albicans*, whereas a minimum of 0.35 cc. of distillate was effective. After eleven months, 0.35 cc. of juice was effective in inhibiting the growth of the same organism, but the distillate appeared to have lost its antibiotic properties completely.

Extracts were tested on *Penicillium* four months after their preparation. Amounts of juice as large as 1 cc. had no complete inhibitory effect on this organism, although it did slow down the growth, control plates showing growth in three days as compared to seven days for test plates. However, later tests using distillate prepared by steam distillation for a relatively short time giving more protoanemonin per ml. of water, resulted in *Penicillium* being inhibited by 1 cc. of distillate.

The distillate was not tested on *R. nigricans* but the effect of the juice on this organism was somewhat surprising. Mycelia appeared on control plates within 48 hours; on plates containing 1 cc. of juice, no growth could be detecteed macroscopically after one week. In plates containing 0.5 cc. juice a small number of spores were seen on the surface of the agar after seventy-two hours, but mycelia were still invisible

macroscopically even after one week. It would seem that the mycelia are stunted by the substance but this has not yet been thoroughly studied.

Low concentrations of protoanemonin were effective in inhibiting the growth of *C. albicans*, *S. aureus*, *B. megaterium*, and *S. lutea*, but higher concentrations were necessary to inhibit the growth of *Penicillium* and *Mycobacterium smegmatis*. *Aerobacter* seemed not to be effected by the concentrations used. It was interesting to note that when low concentrations of protoanemonin were used on *Penicillium* and *Mycobacterium smegmatis*, growth was slowed considerably as evidenced by the fact that colonies did not appear on these plates until at least two days after growth appeared on the control plates.

The concentrations of anemonin used inhibited the growth of only *Sarcina lutea*. The growth of C. *albicans*, *Penicillium*, *Aerobacter aerogenes*, and *Mycobacterium smegmatis* was not visibly inhibited in any way. Tests on *Staphylococcus aureus* and *Bacillus megaterium* were unsatisfactory and no conclusive results were obtained.

A comparison was made between the effects of the antibiotics on the organisms and the characteristics of the organisms. There seemed to be no correlation. Only one reference made by Hill and van Heyningen (3) on the vesicant properties seemed to indicate how the antibiotics act to prevent or retard growth.

The particular species of *R. septentrionales* here studied is apparently more effective in so far as possessing antibiotic properties than may other plants of the *Ranunculaceae*. Boas (1) reported a water *Ranunculus* which appeared to be wholly ineffective, whereas other species, such as *R. acer*, *sceleratus*, *arvensis*, *bulbosus*, and others were reported to be the most effective of those studied. *R. septentrionales* could be placed along with these latter.

Summary

1. Extracts of the plant *Ranunculus septentrionales* possess antibiotic properties.
2. Two extracts may be prepared: a) the "juice", by grinding the plant thoroughly, mixing with water, straining and sterilizing; b) the distillate, by steam distillation of the juice.
3. The active substance, protoanemonin, is isolated from the distillate by extraction with ether. Another antibiotic substance, anemonin, is formed when the protoanemonin polymerizes in air at room temperature.
4. The juice and distillate lost their power of inhibition gradually from month to month, the juice retaining its potency for about eleven months and the distillate for about six months.
5. *Penicillium* and *Rhizopus* are affected less by the juice and distillate than is *C. albicans*, whose growth is inhibited by as little as 0.10 cc. of freshly prepared juice, and 0.15 cc. of freshly prepared distillate.
6. Relatively low concentrations of protoanemonin are effective in inhibiting the growth of *C. albicans*, *Staphylococcus aureus*, *Bacillus megaterium*, and *Sarcina latea*, whereas higher concentrations are needed to achieve this effect on *Penicillium* and *Mycobacterium smegmatis*.

Aerobacter aerogenes was not affected by concentrations of protoanemonin used in this study. Anemonin was effective in inhibiting the growth of *Sarcina lutea* but of none of the other organisms studied.

Literature Cited

1. BOAS, FRIEDRICH, 1934. Beitrage zur Wirkungsphysiologie einheimischer Pflanzen, I. Ber. Deuts. Bot. Ges. **52** :126-130
2. BOAS, FRIEDRICH and RUDOLF STEUDE. 1935. Uber die Wirkung von Anemonin auf Mikroorganismen. Biochem. Ztschr. **279** :417-423.
3. HILL, R. and R. VAN HEYNINGEN. 1951. Ranunculin : the Precursor of the Vesicant Substance of the Buttercup. Biochem. Journ. **49** :332-335.
4. HOLDEN, MARARET, B. C. SEEGAL, and H. BAER. 1947. Antibiotic Activity of Protoanemonin. Proc. Soc. Exp. Biol. Med. **66** :54-60.
5. SUTER, C. M. (ed.). 1951. *Medicinal Chemistry*. New York, John Wiley and Sons, Inc.

Studies of the Control of Oak Wilt Disease in Southern Indiana

R. J. Green, Jr. and L. R. Schreiber, Purdue University

Oak wilt disease, incited by *Ceratocystis fagacearum* (Bretz) Hunt, was first reported in Indiana by Cummins in 1949 (1). Surveys conducted by Stearns and Crowder (6) from 1952 to 1956 established the distribution of this disease in the state. It was shown that oak wilt is more widespread and most destructive in the northcentral and northwestern counties but is also present in several southern counties of the state. Schreiber and Green (4) conducted intensive studies on the actual and potential rates of spread of oak wilt disease in northern and southern Indiana in 1957 and 1958 and made additional surveys of disease incidence, especially in the southern part of the state. These investigations showed that, though the incidence of oak wilt in the southern counties is low, the potential destructiveness of this disease is equally as great in this area as in the northern counties.

Quercus spp. are the most important and numerous tree species utilized by the lumbering and wood-using industries in Indiana. Total harvest of native lumber in 1949 was 183 million board feet with oak comprising 45% of the total. This important industry is located almost exclusively in the southern counties.

Since 1959, emphasis in oak wilt investigations in the Department of Botany and Plant Pathology, Purdue University, has been the development of a suitable control program in the southern areas of the state. This has included aerial survey as a means of detection of oak wilt and the application of eradication practices to contain and eventually eliminate oak wilt as a disease of economic importance from the timberlands of southern Indiana.

Aerial Survey

Aerial surveying has proven to be more efficient than ground survey as a means of detecting oak wilt disease when the terrain is rough and inaccessible. In 1959, several areas, 300 to 400 sq. miles in area, were selected for intensive aerial survey. These were located in parts of Morgan, Monroe, Bartholomew, Jackson, Brown, Scott, Gibson, Franklin, Dearborn, and Ripley counties. The flight pattern for survey was intervals of ½ to 1 mile at altitudes of 300 to 1,000 feet and air speeds of 100 to 115 m.p.h. Air crews[1] consisted of the pilot and 1 or 2 observers. All suspected infection centers were accurately marked on either 7.5 or 15 minute topographic maps. The aerial survey group met with ground

1. The writers wish to acknowledge the assistance of personnel from the Division of Entomology, Indiana State Department of Conservation.

PLATE 1. *A*. Aerial view of oak wilt infection center. *B*. Oak wilt infection center after poisoning and felling of all oaks. *C*. Basal boring of buttress roots for application of silvicide. *D*. Application of silvicide, note saw girdle to reduce upward movement. *E*. Resprouting of stump after poisoning and felling. *F*. Irregular upward translocation of sodium arsenite.

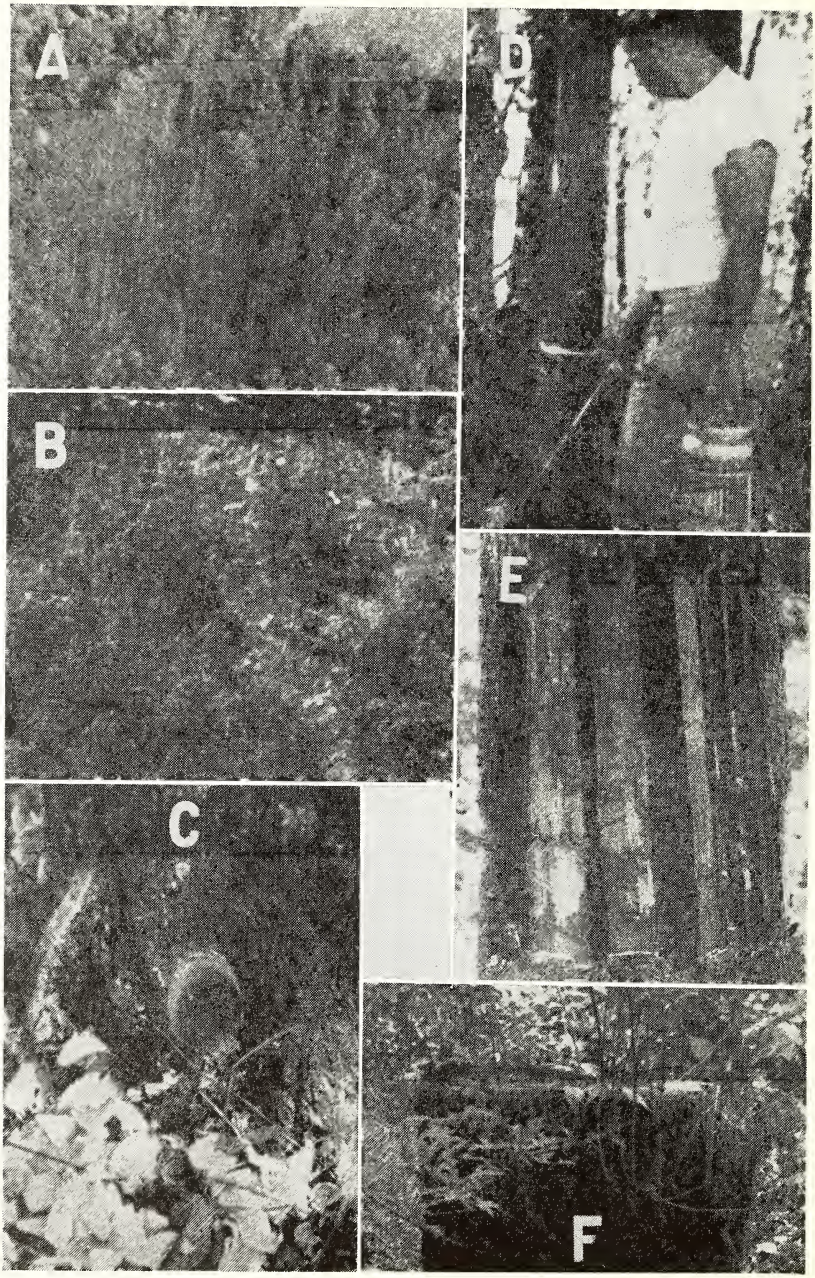


Plate 1

crews and, using the topographic maps marked during aerial survey, the suspect areas were located and specimen samples taken for laboratory isolation attempts of the oak wilt pathogen.

Aerial observers could quickly learn to distinguish oak wilt infection centers by the typical foliage symptoms and the characteristic circular spread of the disease in infected stands. However, single tree infections were more difficult to distinguish and mortality from lightning strike and other causes frequently was confusing. It was also found that ground crews were able to locate suspect areas much more readily if they were marked from the air as well as indicated on topographic maps. Many different techniques were tried and it was found that rolls of toilet tissue dropped from the plane provided the best means of marking suspect areas for ground crews.

The results of the aerial survey for oak wilt incidence, to date, have confirmed the general distribution of oak wilt disease in southern Indiana. These surveys have also shown that the greatest incidence of new infection occurs in the area of existing infection centers. Since the incidence of oak wilt is low in the southern part of the state there appears to be an excellent opportunity to markedly reduce or eliminate this potentially destructive disease from this area by direct control practices.

Eradication Studies 1959-60

In 1959, a number of oak wilt infection centers, located on both public[2] and private lands, were included in studies to determine the effectiveness of eradication practices to prevent further spread of this disease. It has been established (3) that the pathogen may spread from tree to tree via natural root grafts and that such grafts may be found at distances from 30 to 50 feet. Thus, it is necessary to form a barrier of 30 to 50 feet around the infection center to assure against any bridging root grafts between infected and healthy trees.

Each infection center placed under the eradication program was handled as follows: All oaks within the infection center and within a 30 to 50 feet radius of the center were poisoned by drilling holes to a depth of 3 inches in the buttress roots and applying either an aqueous solution sodium arsenite or 2,4,5T (2,4,5 trichlorophenoxyacetic acid) in kerosene. The roots were drilled with a 1½ inch auger bit attachment for a chain saw. After poisoning, the trees were felled and either piled for disposal or, in some cases, salvaged for pulp or other uses. In either case, extreme care was taken in the handling and disposal of the felled trees to prevent mechanical injury to the other trees of the stand.

In some cases, sprouting was observed from the cut stumps the following season. These sprouts were promptly sprayed with 2,4,5T solution. It was noted that trees poisoned with sodium arsenite frequently sprouted because of the uneven distribution of the poison in the vascular tissues. In some instances, the poisoned trees were girdled with a circumferal saw cut in an effort to get more complete lateral and downward translocation of the silvicide. The girdling was done, also, to hasten drying

2. The writers wish to acknowledge the assistance of the Director and staff of the Division of Forestry, Indiana State Department of Conservation.

of the poisoned tree and thus reduce formation of the ascigerous stage of the pathogen. This spore stage is assumed to be the principal source of inoculum for "long distance" spread of the pathogen (2) (5).

To date, 10 infection centers have been included in the oak wilt eradication studies. These include 3 centers in Pike County State Forest and the remainder on private land in Dearborn, Brown, Clark, Washington and Dubois counties. Additional areas will be placed under eradication as they become available. It is presumed that a period of 3 to 5 years will be required before final conclusions can be drawn concerning the effectiveness of this method of control. If these control practices are effective in the areas selected for study, oak wilt can be controlled in southern Indiana by routine aerial survey and regulatory practices.

Literature Cited

1. CUMMINS, G. B. 1949. Oak wilt in Indiana. Plant Dis. Reptr. 33(8).
2. DORSEY, C. K., F. F. JEWELL, J. G. LEACH and R. P. TRUE. 1953. Experimental transmission of oak wilt by four species of Nitidulidae. Plant Dis. Reptr. 37(8) : 419-420.
3. KUNTZ, J. E. and A. J. RIKER. 1956. Oak Wilt. Wisconsin Conservation Dept. and U. S. D. A. Bul. 519 :1-12.
4. SCHREIBER, L. R. and R. J. GREEN, JR. 1959. The occurrence and prevalence of oak wilt in Indiana. Master of Science Thesis, Purdue University.
5. STAMBAUGH, W. J., C. L. FERGUS, F. C. CRAIGHEAD and H. E. THOMPSON. 1955. Viable spores of *Endoconidiophora fagacearum* from bark and wood-boring beetles. Plant Dis. Reptr. 39(11) :867-871.
6. STEARNS, F. and H. CROWDER. 1957. Oak wilt in southern Indiana. Proc. Ind. Acad. of Sci. 66 :63.

Variability of Telial Formation of *Puccinia coronata*

David E. Zimmer and John F. Schafer, Purdue University

The variability exhibited by the crown rust fungus, *Puccinia coronata* Cda. var. *avenae* Fras. and Led. is not limited to pathogenicity differences but also occurs in other physiological characters. Differential development of the telial stage has been observed for a number of rust fungi. Previous investigators attempted to show by experimentation or observation that telial formation was affected by differences or changes in one or a combination of the following: (1) condition of host vigor, (2) stage of host development, (3) relative host resistance, (4) inherent character of the fungus, and (5) environment.

Waters (12), Johnson (4), and Gordon (3) have reviewed and discussed the literature on factors affecting telial formation of rust fungi. Magnus (5) in 1891 first proposed that the relative condition of the host plant affected the occurrence of telia. Gassner (2) concluded that the determining factor was physiologic aging, the stage of host development governing teliospore formation. Bailey (1) subsequently reported the stage of host development not to be important for *P. graminis* Pers. f. sp. *avenae*. Parker (7) reported that the production of telia of crown rust on oat seedlings was related to host resistance. Murphy (6) observed a similar relationship on both seedlings and adult plants. Parson (8), however, found some cultures to form telia as early on susceptible varieties as on resistant.

Raines (10) believed that the protoplasmic constitution of the fungus itself was the important factor, finding wide differences in the tendency towards telial production in different cultures of the crown rust fungus. In further observations of such differences Bailey (1) and Gordon (3) reported a correlation between virulence and rapidity of teliospore development for cultures of *P. graminis* f. sp. *avenae*. Parson (8) and Murphy (6), in contrast, suggested that early telial formation may be characteristic of narrowly specialized races of *P. coronata*. Parson as well as Murphy also reported that some cultures of *P. coronata* studied never produced telia. Murphy observed differences in telial development among different cultures of the same race of *P. coronata*.

Waters (12) reported telial production to be related to a lack of maintenance of vegetative vigor and thus influenced by any internal or external combination of factors affecting this, such as light, temperature, or moisture. Peturson (9) and Simons (11) showed that telia of *P. coronata* developed more rapidly at 25° C than at lower temperatures. Johnson (4) and Gordon (3) found that higher temperature also favored early telial formation of *P. graminis* f. sp. *tritici* and *P. graminis* f. sp. *avenae*, respectively.

The present investigation was undertaken to obtain knowledge of telial formation pertinent to the development of telia for studies involving the completion of the life cycle of *P. coronata*. A preliminary report has been made (13).

Materials and Methods

Single monosporus cultures each of races 202, 203, 264, 294, and 295 and 3 monosporus cultures of race 293 of *P. coronata* var. *avenae* were studied. The relative rapidity of telial formation on seedling and mature plants of resistant and susceptible host varieties was investigated by inoculating each culture on the oat varieties, Appler (CI 1815), Bond (CI 2788), Canuck (CI 4024), and Clintland (CI 6701). After incubation the plants were placed on greenhouse benches and observed daily for the appearance of telia. Appler and Bond were susceptible to all cultures tested; Clintland was highly resistant to races 202 and 203 but susceptible to the others; whereas Canuck was susceptible to races 202, 203, and 264, but only moderately susceptible to the cultures of races 293, 294, and 295.

The influence of temperature on telial formation of races 202, 203, 293 (culture B), 294, and 295 on these oat varieties was determined by inoculating seedlings and subjecting them to constant temperatures of 60°, 70°, and 80° F at a photoperiod of 16 hours.

Races 264 and 293 (culture C) which did not produce telia were inoculated on these 4 and additional oat varieties in the seedling, juvenile, and mature plant stages. These inoculated plants were subjected to one or a combination of the following treatments: (1) temperature fluctuation, 12 hours in light at 80° F followed by 12 hours in darkness at 60° F, (2) low fertility, (3) low soil moisture, and (4) removal of infected leaves and floating upon a 7% sucrose solution.

Results

The results of the test with different rust cultures, oat varieties, and stages of growth are presented in table 1. These show that different

Table 1. Days after inoculation of seedlings and mature plants of 4 oat varieties that telia of *P. coronata* were first observed.

Race	Days to telial formation							
Variety:	Clintland		Appler		Canuck		Bond	
Stage:	Seedling	Mature	Seedling	Mature	Seedling	Mature	Seedling	Mature
202	14^R	15^R	17	16	20	20	18	18
203	24^R	26^R	20	22	22	25	29	19
264	*—	—	—	—	—	—	—	—
293A	14	21	14	23	24	26	16	22
293B	18	23	17	22	22	25	18	20
293C	*—	—	—	—	—	—	—	—
294	21	24	23	21	20	24	19	19
295	16	18	17	19	21	29	16	21

R = Resistant reaction
* = No telia produced

cultures of the same race as well as different races vary in their ability and rapidity in producing telia. No relationship was shown between the virulence of a particular culture on the differential variety Clintland and the rapidity of telial formation, nor was there any relation of host resist-

ance and susceptibility to the rate of telial formation of the 2 differential races, 202 and 203.

The time required for the initiation of telia following inoculation of these 4 varieties in the seedling stage with the 6 telia-producing cultures was generally less than the time required on the same varieties inoculated in the mature plant stage; however, the relative differences varied widely and exceptions were found (table 1).

Increase in incubation temperature decreased the time required for the initiation of telia (table 2). The difference between 60° and 70° F

Table 2. Days after inoculation that telia of *P. coronata* were first observed on 4 oat varieties kept at 3 constant temperatures.

Race	Variety	Days to telial formation		
	Temperature:	60°F	70°F	80°F
202	Clintland	25	18	14
	Appler	26	20	17
	Canuck	28	24	19
	Bond	28	22	17
203	Clintland	32	24	22
	Appler	31	22	20
	Canuck	33	24	21
	Bond	30	21	16
293B	Clintland	28	23	16
	Appler	28	21	19
	Canuck	29	25	23
	Bond	29	22	18
294	Clintland	29	24	16
	Appler	31	23	19
	Canuck	30	24	20
	Bond	28	21	17
295	Clintland	23	19	16
	Appler	26	23	19
	Canuck	27	24	20
	Bond	24	21	17
AVERAGE		28.3	22.3	18.3

resulted in an average decrease of 6 days in time of telial development of 5 cultures of *P. coronata* on 4 oat varieties. The difference between 70° and 80° F further decreased the time required for telial formation by 4 days.

The culture of race 264 tested and culture C of race 293 did not produce telia under any experimental conditions including the addition of other host varieties to broaden the available range of host-parasite inter-

actions, fluctuation of temperature, subjection to low fertility and low moisture, and floating of detached leaves on a 7% sucrose solution.

Discussion

Rapidity of telial formation does not appear to be characteristic of a race as defined by its specific pathogenicity, in agreement with the earlier report of Murphy (6). Although 3 cultures of race 293 tested were similar in specific pathogenicity, they differed in their ability and rate of telial formation. Two cultures produced telia readily on all varieties tested, but at somewhat different rates, while the remaining culture was similar to race 264 in that it did not produce telia. Race 264 has different specific virulences than race 293 and a wider range of virulence. The similarity of races 264 and 293C in failing to produce telia and the differences among the cultures of race 293 suggest that no correlation either positive or negative exists between specific virulence or range of virulence and rate of telial production.

All telia-producing monosporus cultures developed telia more readily on some varieties than on others. Thus, telial production is not due entirely to inherent tendencies of the rust. None of the 4 oat varieties tested affected in a consistent manner the rapidity at which a number of cultures produced telia. Therefore, the rapidity at which an element of the rust population produces telia appears independent of reaction type and host variety as well as specific virulence or range of virulence but dependent on the specific capabilities of the rust entity concerned in relation to the specific host-parasite combination.

The results obtained with the effect of temperature on rate of telial development support the previous work in this area.

Failure to stimulate races 264 and 293C to produce telia suggests that these cultures may lack factors essential for telial formation. As the major source of primary inoculum of the cereal rusts consists of airborne urediospores, it is doubtful if this deficiency has any adverse effect on perpetuation in nature of such a rust. The inability of a particular race to produce telia may actually favor multiplication in that uredial production continues throughout the growing season. Gordon (3) proposed that the rapidity at which a given race of *P. graminis* f. sp. *avenae* produced telia was inversely related to the prevalence of that race.

Summary

Eight monosporus cultures representing 6 races of *P. coronata* var. *avenae* were investigated for telial formation. The rapidity at which a culture produced telia was not correlated with range of virulence of the pathogen, specific virulence of the pathogen, resistance of the host, or host maturity. Rapidity of telial formation appeared to be a function of a specific relationship existing between the particular host and parasite. Temperature was found to directly alter the rate of telial formation. A culture each of races 264 and 293 did not produce telia under any experimental conditions tried, and thus may not have the capacity to produce telia.

Literature Cited

1. BAILEY, D. L. 1925. Physiologic specialization in *Puccinia graminis avenae* Erikss. and Henn. Minn. Agr. Exp. Sta. Tech. Bul. 35, 35 pp.

2. GASSNER, G. 1915. Die Teleutosporenbildung der Getreiderostpilze und ihre Bedingungen. Ztschr. Bot. **7**:65-120.

3. GORDON, W. L. 1933. A study of the relation of environment to the development of the uredinial and telial stages of the physiologic forms of *Puccinia graminis avenae* Erikss. and Henn. Sci. Agr. **14**:184-237.

4. JOHNSON, T. 1931. A study of the effects of environmental factors on the variability of physiologic forms of *Puccinia graminis tritici* Erikss. and Henn. Can. Dept. Agr. Bul. 140, 76 pp.

5. MAGNUS, P. 1891. Ueber das Auftreten der Stylosporen bei den Uredineen. Ber. deutsch. Bot. Ges. **9**:85-92.

6. MURPHY, H. C. 1935. Physiologic specialization in *Puccinia coronata avenae*. U. S. Dept. Agr. Tech. Bul. 433, 48 pp.

7. PARKER, J. H. 1918. Greenhouse experiments on the rust resistance of oat varieties. U. S. Dept. Agr. Bul. 629, 16 pp.

8. PARSON, H. E. 1927. Physiologic specialization in *Puccinia coronata avenae*. Phytopathology **17**:783-790.

9. PETURSON, B. 1930. Effect of temperature on host reactions to physiologic forms of *Puccinia coronata avenae*. Sci. Agr. **11**:104-111.

10. RAINES, M. A. 1922. Vegetative vigor of the host as a factor influencing susceptibility and resistance to certain rust diseases of higher plants. II. Amer. J. Bot. **9**:215-238.

11. SIMONS, M. D. 1954. The relationship of temperature and stage of growth to the crown rust reaction of certain varieties of oats. Phytopathology **44**:221-223.

12. WATERS, W. C. 1928. The control of teliospore and urediniospore formation by experimental methods. Phytopathology **18**:157-213.

13. ZIMMER, D. E., SCHAFER, J. F., and GRIES, G. A. 1960. Studies on teliospore formation and germination in *Puccinia coronata*. (Abs.) Proc. Ind. Acad. Sci. **69**: 107-108

Morphology of the Spermogonium of *Gymnoconia peckiana*, A Rust Fungus[1]

Y. HIRATSUKA and G. B. CUMMINS, Purdue University

This paper describes the morphology of the spermogonium of *Gymnoconia peckiana* (Howe) Trott., the causal agent of the orange rust disease of *Rubus*. The material used was collected adjacent to the Purdue University campus during the spring of 1960 and was studied in stained and unstained free-hand sections.

Kursanov (6) and Buller (2) have illustrated the spermogonia of this fungus, but the descriptions in most taxonomic treatises still are either incorrect or insufficiently descriptive. Dietel (4) described them as ". . . subcuticular, kegelförmig . . .", Arthur (1) as ". . . abundant, columnar . . .", Gäumann (5) as ". . . kegelförmig vorstehend, subkuticular . . .", and Cummins (3) as ". . . subcuticular." Since the structure and position of the spermogonium is considered to be important in the definition of genera, we have restudied it in *Gymnoconia*.

Structure and Development

The spermogonia of this fungus are produced by a systemic and perennial mycelium and are uniformly distributed on both sides of the leaf. They are initiated by a layer of fused hyphae located just beneath the epidermis of the host plant. The spermogonial primordia push out between the epidermal cells (Fig. 1) causing them to separate but not

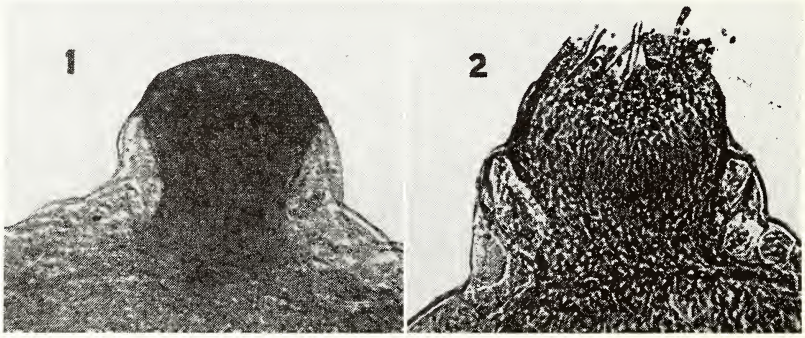


Fig. 1. Immature stage showing the columnar shape of the immature spermogonium of *Gymnoconia* and the bounding elevated epidermal cells of the host plant. The apex is still covered by the cuticle.

Fig. 2. A mature spermogonium; the cuticle has ruptured and the sporogenous layer is elevated to the level of the epidermis. The protruding hyphae are flexuous hyphae. X 240

rupture. Because the development vertically is both more rapid and greater than laterally, the maturing spermogonium assumes the shape of a truncated column (Fig. 1). The column is composed mainly of parallel

1. Contribution from the Department of Botany and Plant Pathology. This research was supported by a Grant-in-aid from the National Science Foundation.

and compacted spermatiophores with the spermatia produced at or slightly above the level of the epidermis of the host plant (Fig. 2). Until maturity is attained and spermatia are produced, the spermogonia are covered by the cuticle of the host.

The mature spermogonia average 100 μ in length and 99μ in width at the apex. They have neither a peridium nor paraphyses and are bounded only by a few upturned epidermal cells. Flexuous hyphae (Fig. 2) protrude from the apex of the spermogonia, as reported by Buller (2).

Discussion

The spermogonium of *Gymnoconia* is unique in some respects. It originates subepidermally but it differs markedly from the typical subepidermal spermogonium of *Puccisia* and *Gymnosporangium* in that the sporogenous layer is almost superficial at maturity rather than embedded in the mesophyll tissue. The apex of the spermogonium is covered only by the cuticle but typical subcuticular spermogonia, as those of *Prospodium, Pileolaria,* and *Diorchidium,* have a broad base that is seated upon the outer wall of the epidermis and there is no separation of the cells. A third type is called intraepidermal *(Gerwasia* and *Frommea)* because the spermogonium is initiated and largely or completely matures within the epidermal cells with the destruction of some of the anticlinal walls and rupture of the outer epidermal wall. The spermogonium of *Gymnoconia* has nothing in common with this type.

Literature Cited

1. ARTHUR, J. C. 1934. Manual of the rusts in Unitel States and Canada. Purdue Research Foundation, Lafayette, Indiana. 438 p.
2. BULLER, A. H. R. 1950. Researches on fungi. Vol. 7. University of Toronto Press, Toronto, Ontario. 458 p.
3. CUMMINS, G. B. 1959. Illustrated genera of rust fungi. Burgess Publ. Co. Minneapolis, Minnesota. 131 p.
4. DIETEL, P. 1928. Reihe Uredinales. Nat. Pflanzenfam. 2 Aufl. 6 :24-98.
5. GAUMANN, E. 1959. Die Rostpilze Mitteleuropas. Beitr. Kryptogamenfl. Schweiz. Vol. 12 Büchler and Co. Bern. 1407 p.
6. KURSANOV, L. 1910. Zur sexualitat der Rostpilze. Zeits. Bot. 2 :83-85.

CHEMISTRY

Chairman: H. B. BURKETT, DePauw University

WARREN BRANDT, Purdue University, was elected chairman for 1961

ABSTRACTS

Chemical Terms Derived from Greek. NED GUTHRIE, Hanover College.—It has been the author's experience in the teaching of chemistry that students tend to memorize the meaning of scientific terms instead of reasoning the meaning from the meaning of familiar words derived from the same Greek root or prefix. Gerald R. Boezer published a list of Greek and Latin roots with one or two examples to illustrate each. This paper gives additional examples from the most widely used roots, mainly in the field of chemistry, some from other sciences and a few from non-scientific fields to make the student conscious of this method of building a useful vocabulary. This paper is confined to words derived from the Greek. From five to ten words are given as examples of each root or prefix. Following is a list of roots or prefixes. (A similar paper is being prepared from words derived from Latin.)

1. A, An. Without or Not.
2. Ana. Up or Upward.
3. Ampho, Amphia. Both, both sides, Around. (Latin is Ambi.)
4. Anti. Against.
5. Bar. Heavy.
6. Bio. Life.
7. Bole. Throw or Stroke.
8. Cata. Down.
9. Chol. Bile.
10. Chrom. Color.
11. Cline. Slope or Lean.
12. Cycle. Circle, Wheel, Ring.
13. Cyto. Cell.
14. Dia. Through, Across, Between.
15. Dys. Hard, Difficult, Ill.
16. Endo. Within, Into.
17. Epi. On, Upon, Beside, Over.
18. Erg. Work.
19. Erythro. Red.
20. Eu. Good, Well, Easily.
21. Ex, E. Out.
22. Gen. To produce or form.
23. Geo. Earth.
24. Glyco. Sweet.
25. Gon. Angle.
26. Graph. Write.
27. Hodes or Ode. Road or Way.
28. Homo. Same or Alike. (Homo from Latin means man.)
29. Hydro. Water.
30. Hypo. Under, Down, Beneath.
31. Iso. Equal or Same.
32. Leuco. Light or White.
33. Lith. Stone.
34. Lysis. Loosen, Split.
35. Mer. Part.
36. Meta. Between, Along with, After, Over.
37. Micro. Small.
38. Morph. Form.
39. Neo. New.
40. Ortho. Straight, Regular, Right, True, Correct.
41. Para. Beside, Beyond.
42. Peri. Around.
43. Petro. Rock or Stone.
44. Philo. Loving, Fond of.
45. Phos, Photo. Light.
46. Poly. Many.
47. Pyro. Fire, Heat.
48. Scope. View.
49. Stat. Standing or Stationary.
50. Stereo, Stere. Solid, Space.
51. Sym. Syn. With, Together.
52. Therm. Heat.
53. Tom, Otomy. To cut into.
54. Trope, Tropos. Turn or Change.

The Uultraviolet Absorption Spectra of Some Unsymmetrical Disulfides.[1,2] E. CAMPAIGNE, J. TSURUGI and W. W. MEYER, Indiana University.—The ultraviolet absorption curves of certain unsymmetrical diaryl disulfides, Ar-S-S-Ar', were calculated as one-half the sum of the absorption curves of the two symmetrical disulfides, ArSSAr and Ar'SSAr'. Slight deviations from the calculated values in the observed curves were consistent with inductive effects of groups attached to sulfur in the two halves of the molecule, ArS- and Ar'S-. No transmission of electronic effects through the sulfur-sulfur bond could be detected in the ultraviolet spectra of the diaryl disulfides.

The Spectra of Some Schiff Bases of p-Aminoazobenzene. JOHN A. RICKETTS and CHUNG SOOK CHO, DePauw University.—The spectra of the molecules, N,N-Dimethyl-p-phenylazoaniline, N,N'-Dibenzal-1,4-diaminobenzene, N-(p-dimethylaminobenzal)aniline, N-Benzal-p-phenylazoaniline, N-(p-dimethylaminobenzal)-p-phenylazoaniline, and 1-Methyl-4-carbostyrilcarboxaldehyde-p-phenylazoanilineanil, were determined in both dry ethanol and ethanol solutions of varying acid strengths in the region of 2200 to 6000 A°. In addition the infrared spectra of these molecules were determined in carbon tetrachloride. The first and second dissociation constants of the compounds were determined by applying the Lambert-Beer law.

Acid-Catalyzed Decarbonylation of 2,4,6-Trimethoxybenzaldehyde. An Accompanying Condensation Reaction. HOWARD BURKETT and JOHN CASSADY, DePauw University.—Normally under a wide variety of conditions of treatment with mineral acids and mineral acids with added salts 2,4,6-trimethoxybenzaldehyde at ca. 10^{-5} to 10^{-4} molar concentration yielded only 1,3,5-trimethoxybenzene or, at the higher acid concentrations, subsequently phloroglucinol by demethylation of the initial product. If the concentration of the 2,4,6-trimethoxybenzaldehyde was above ca. 10^{-3} molar, a red solution and a red precipitate were obtained from the reaction mixture in strong hydrochloric acid, hydrobromic acid or perchloric acid. Removal of acid from the red solid yielded a white solid, 2,4,6,2',4',6',2'',4'',-6''-nonamethoxytriphenylmethane, a new compound. Titration indicated the red solid to be a 1:1 adduct between this compound and the mineral acid used. A kinetic study demonstrated that the new compound was formed by reaction of the aldehyde with 1,3,5-trimethoxybenzene from the decarbonylation of the aldehyde.

---

1. Contribution from the Chemistry Laboratories of Indiana University.
2. A technical report prepared for the Office of Ordnance Research, United States Army, Contract DA 33-008-ORD 1916.

Stepwise Construction of Sulfur and Selenium Chains

ROBERT EARL DAVIS[1], Purdue University

Introduction

Sulfur and selenium have numerous allotropic forms, the most stable in the standard state having a high degree of catenation. Yet reactions of these elemental forms generally produce materials containing only a few VIb atoms. Likewise numerous compounds containing only one or two VIb atoms serve as sources for long catenated chains. Two such reactions will be discussed in great detail.

The Decomposition of Sodium Thiosulfate in Acid

The decomposition of acidified thiosulfate has received much study. The products[2,9,13] have been determined and various kinetic investigations have been made.[2,8,9,11,12,13] The products of the reaction are sulfur dioxide, S_6, S_8, colloidal sulfur, various polythionic acids ($H_2S_xO_6$), and hydrogen sulfides. The rate expressions of production of sulfur

$$d(\text{sulfur})/dt = k_I\ (S_2O_3^{-2})^{3/2}\ (H^+)^{1/2} \qquad (1)$$

and of sulfur dioxide

$$d(SO_2)/dt = k_{II}\ (S_2O_3^{-2})^2\ (H^+)^1 \qquad (2)$$

have been observed.

These data have been interpreted by the author[6] as follows:

$$S_2O_3^{-2} + H^+ \overset{K_2}{\rightleftharpoons} HS_2O_3^- \qquad (3)$$

$$HS_2O_3^- + S_2O_3^{-2} \overset{k_1}{\rightarrow} HS_3O_3^- + SO_3^{-2} \qquad (4)$$

$$HS_3O_3^- + S_2O_3^{-2} \overset{k_2}{\rightarrow} HS_4O_3^- + SO_3^{-2} \qquad (5)$$

$$HS_xO_3^- + S_2O_3^{-2} \overset{k_x}{\rightarrow} HS_{x+1}O_3^- + SO_3^{-2} \qquad (6)$$

$$HS_8O_3^- + S_2O_3^{-2} \overset{k_7}{\rightarrow} HS_9O_3^- + SO_3^{-2} \qquad (7)$$

$$HS_9O_3^- \overset{k}{\rightarrow} S_8 + HSO_3^- \qquad (8)$$

The derivation of the rate equation from this reaction scheme can be easily done when

(i) it is realized that in determining the rate of sulfur appearance the extent of reaction is only 0.01%, *i.e.* $d(S_2O_3^{-2})/dt = d(HS_2O_3^-)/dt = 0$

(ii) the matrix of equations with these boundary conditions is now reduced to linear, first-order differential equations containing simplifying symmetry properties and

(iii) several expansion series are used.

---

1. The author wishes to thank the Walter Reed Army Institute of Research for a grant under which this work was completed. The project was begun while the author was an NSF postdoctoral fellow at the Massachusetts Institute of Technology in 1958-59.

The theory predicts a rate

$$d(\text{sulfur})/dt \propto (S_2O_3^{-2})^n \ (H^+)^{1/2} \qquad 2 > n > 1$$

compared to the experimental

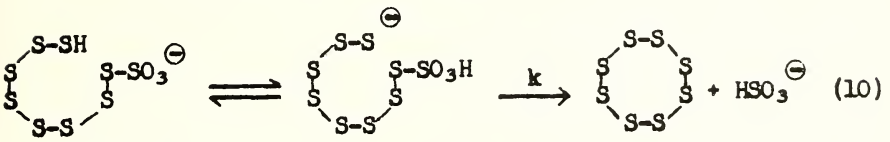
$$d(\text{sulfur})/dt \propto (S_2O_3^{-2})^{3/2} \ (H)^{1/2}$$

When the extent of reaction is greater, $d(S_2O_3^{-2})/dt \neq 0$, and the system of competitive, bimolecular reactions cannot be solved in an analytical form. The steady state approximation can be used and the rate expression found is proportional to $(S_2O_3^{-2})^2 \ (H^+)^1$, as found experimentally.

Reactions (4)–(8) are visualized as nucleophilic displacement reactions at the sulfur atom. Equation (4) can be described as

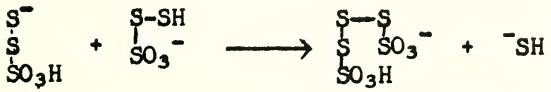
$$H\text{–}S\text{–}\overset{*}{S}O_3^- + S\text{–}SO_3^{-2} \xrightarrow{k_1} H\text{–}S\text{–}S\text{–}SO_3^- + \overset{*}{S}O_3^{-2} \qquad (9)$$

The sulfopolysulfane intermediate, $HS_9O_3^-$, decomposes in an unimolecular reaction forming an S_8 ring.



(10)

Hexatomic sulfur would be obtained from $HS_7O_3^-$. Colloidal sulfur could be S_x macro rings and/or chains of $H\text{–}S_x\text{–}SO_3H$ or $HSO_3\text{–}S_xSO_3H$ (x very large). The formation of the polythionates and hydrogen sulfide can be formulated as



(11)

The polysulfanes could be formed in analogous displacement reactions. All of the reactions steps are consistent with radiochemical data.

The Oxidation of Iodide Ion with Selenous Acid

The rate of oxidation of iodide ion with selenium dioxide in aqueous acid medium[10]

$$H_2SeO_3 + 4H^+ + 6I^- \underset{K=6.8\times10^{13}}{\overset{K}{\rightleftharpoons}} 1/x\ Se_x + 2I_3^- + 3H_2O \qquad (12)$$

is

$$\text{rate} = \frac{(H_2SeO_3)\ (H^+)^3\ (I^-)^4}{k_\alpha\ (I_3^-) + k_\beta\ (H^+)\ (I^-)} \qquad (13)$$

The interpretation of these data involves the following postulated scheme:

$$H_2SeO_3 + H^+ \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} HSeO_2^+ + H_2O \qquad (14)$$

$$HSeO_2^+ + I^- \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} HSeO_2I \qquad (15)$$

$$HSeO_2I + H^+ \underset{k_{-3}}{\overset{k_3}{\rightleftharpoons}} H_2SeO_2I^+ \qquad (16)$$

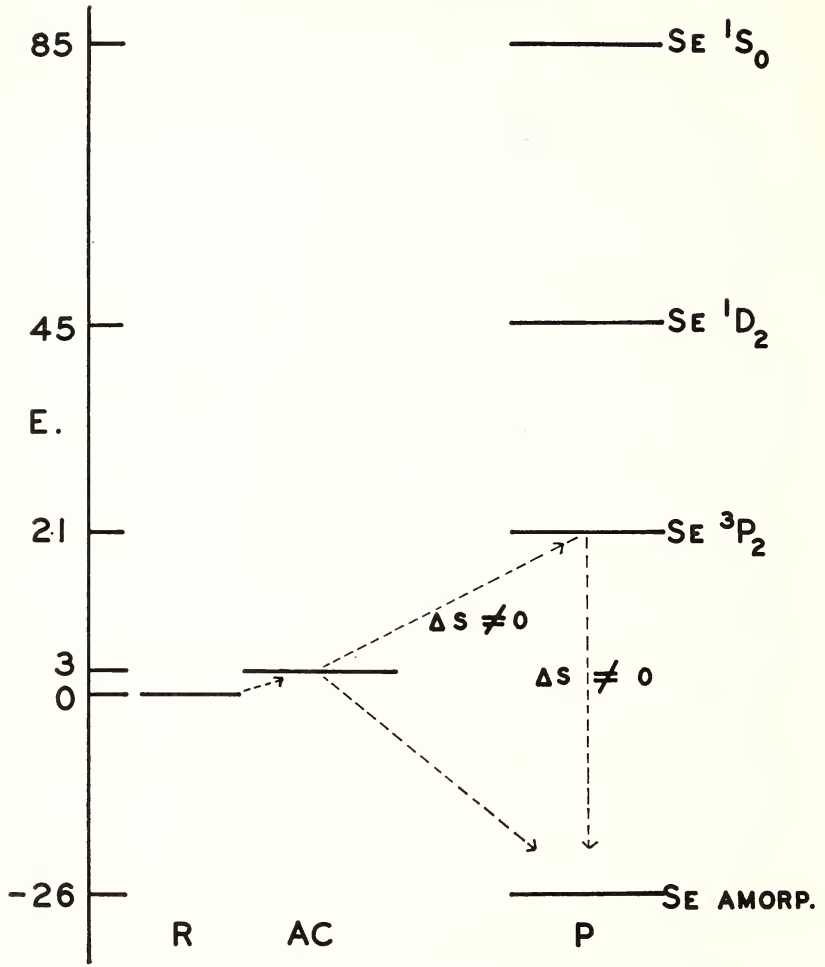


Fig. 1.—Energy profile of reaction (12.). E in Kcal. R, reactants; AC, activated complex; P, products. Energy levels of the products ($2I_3^- + 3H_2O + \frac{1}{x} Se_x$ are calculated with only the selenium promoted to higher states. Spin restricted transitions are labelled $\Delta S \neq 0$.

$$H_2SeO_2I^+ + 2I^- \underset{k_{-4}}{\overset{k_4}{\rightleftharpoons}} I_3^- + HOSeOH \qquad (17)$$

$$HOSeOH + H^+ \underset{k_{-5}}{\overset{k_5}{\rightleftharpoons}} HOSe^+ + H_2O \qquad (18)$$

$$HOSe^+ + I^- \underset{k_{-6}}{\overset{k_6}{\rightleftharpoons}} HOSeI \qquad (19)$$

$$HOSeI + 2I^- \underset{k_{-7}}{\overset{k_7}{\rightleftharpoons}} I_3^- + HSeO^- \quad (20)$$

$$HSeO^- + H^+ \underset{k_{-8}}{\overset{k_8}{\rightleftharpoons}} HSeOH \quad (21)$$

$$HSeOH + H^+ \underset{k_{-9}}{\overset{k_9}{\rightleftharpoons}} HSeOH_2^+ \quad (22)$$

$$HSeOH_2^+ + HSeO_3^- \underset{k_{-10}}{\overset{k_{10}}{\rightleftharpoons}} HSe\text{–}SeO_3H + H_2O \quad (23)$$

$$2HSeSeO_3H \underset{k_{-11}}{\overset{k_{11}}{\rightleftharpoons}} HSe\text{–}Se\text{–}SeO_3H + H_2SeO_3 \quad (24)$$

$$HSe\text{–}Se\text{–}SeO_3H + HSe\text{–}SeO_3H \underset{k_{-12}}{\overset{k_{12}}{\rightleftharpoons}} HSe_3SeO_3H + H_2SeO_3 \quad (25)$$

$$HSe_xSeO_3H + HSeSeO_3H \underset{k_{-x}}{\overset{k_x}{\rightleftharpoons}} HSe_{x+1}SeO_3H + H_2SeO_3 \quad (26)$$

$$HSe_8SeO_3H \underset{k_{-17}}{\overset{k_{17}}{\rightleftharpoons}} Se_8 + H_2SeO_3 \quad (27)$$

$$HSe_ySeO_3H \underset{k_{-y}}{\overset{k_y}{\rightleftharpoons}} Se_y + H_2SeO_3 \quad (28)$$

As the reaction order requires that k_{-i} $(i \leqslant 5) \neq 0$, k_{-6} was set equal to zero. This reduces the rate expression to

$$\text{rate} = \left[\frac{(H_2SeO_3)\,(H^+)^3\,(I^-)^4 k_1 k_2 k_3 k_4 k_5 k_6}{k_{-1}k_{-2}k_{-3}k_{-4}k_{-5}(I_3^-) + k_1 k_2 k_3 k_5 k_6 (H^+)\ (I^-) + Q} \right]$$

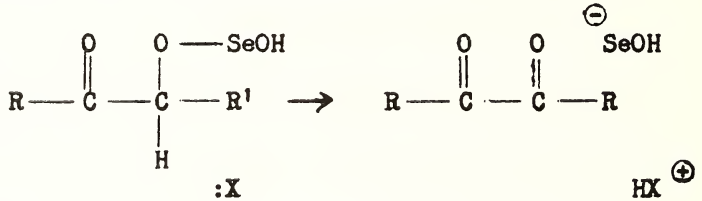
where $Q = f\,[k_2, k_3 \ldots k_6, k_{-1}, \ldots k_{-5}, (H^+)\,(I^-)\,(I_3^-)] =$ small value experimentally.

The postulated chemical steps are based on analogies of the behavior of the oxy acids of sulfur and selenium.[7] The stepwise buildup of selenium chains is an extension of the mechanism of the decomposition of thiosulfate. The intermediate of reaction (21), HSeOH, is not decomposed in this scheme to water and atomic Se. The ground state of atomic selenium with a valency configuration of $[4s]^2[4p]^4$ is $^3P_2$. The singlet $^1D_2$ state of the same designation lies 27.37 kcal. about the ground state[1] while the $^1S_0$ state is 64.17 kcal. above $Se(^3P_2)$. Then atomic Se has a $\Delta H°f$ of + 48.37 kcal./mole from the gray hexagonal form. Thus the $\Delta H°f$ of the reaction $\frac{1}{x} Se_{x\,(amorp)} \rightarrow Se_{(g)}\ (^3P_2)$ can be calculated to +47.32 kcal./mole at 25°.

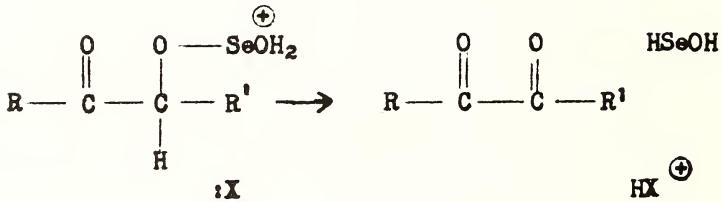
It is, therefore, quite unlikely that atomic selenium is a reaction intermediate. The transition from a singlet to a triplet state would be a relatively slow process due to spin restrictions even though the selenium atom has moderately strong spin-orbit coupling. Besides $Se(^3P_2)$ is a

high energy species and a higher activation energy should be observed if it is an intermediate. The stepwise buildup of a selenium chain by nucleophilic displacement reactions is then a more attractive theory. These criteria apply to other oxidations by SeO_2 and to reactions involving elemental selenium. Kinetic data on several of these reactions will be published in the near future.

In particular, evidence has been obtained for the importance of esters of HOSeOH during the selenium dioxide oxidation of ketones.[3,4,5] A postulated reaction sequence would be ($\overset{\cdot\cdot}{X}$ a general base)



or



The ultimate fate of the HSeOH would be given by equations (21) through (28) and the final emergence of an Se_8 ring

Energetics of Sulfur and Selenium

Foundational to the foregoing discussion has been the energetics of the various allotropic forms of these VIa elements. The following tables summarize the data available.

Heats of Formation of Various Allotrops of Sulfur

State		$\Delta H°_{298}$ kcal./g. atom	
S_8	α	0.00	
S_8	β	0.07	
S_6		25.3	gas phase
S_2	$^3\Sigma_g^-$	29.86	
	$^1\Delta_g$		
	$^1\Sigma_g^+$		
	$^3\Sigma_u^-$	120.8	
	$(^3\pi_u)$	198	
S	$^3P_2$	53.25	
	$^1D_2$	79.5	
	$^1S_0$	119.5	

Heats of Formation of Various Allotrops of Selenium

State		$H°_{298}$ kcal/g. atom	
Se	hexagonal	0.00	
	precipitated	1.05	
Se_2		33.14	gas
Se	$^3P_2$	48.23	
	$^3P_1$	53.8	
	$^3P_0$	55.4	
	$^1D_2$	75.5	
	$^1S_0$	112.3	

These data can be used to exclude monoatomic and diatomic sulfur or selenium as intermediates in numerous reactions.

Literature Cited

1. ATOMIC ENERGY LEVELS. 1952. Vol. II. Cir. 467, U. S. National Bur. Standards, p. 150.
2. BASSENT, H., and R. G. DURRANT. 1927. The Inter-relationships of the Sulfur Acids. J. Chem. Soc. **1927** : 1401.
3. COREY, E. J., and J. P. SCHAEFFER. 1960. Studies on the Mechanism of Oxidation of Ketones by Selenium Dioxide (Part I). J. Am. Chem. Soc. **82** : 918.
4. COREY, E. J. 1959. Organic Symposium of the Am. Chem. Soc. Seattle.
5. DAVIS, R. E. 1958. Displacement Reactions at the Sulfur Atom. Thesis. Harvard.
6. DAVIS, R. E. 1958. Displacement Reactions at the Sulfur Atom. I. An Interpretation of the Decomposition of Acidified Thiosulfate. J. Am. Chem. **80** : 3565.
7. DAVIS, R. E. Unpublished Data.
8. DINEGAR, R. H., R. M. SMELLIE, and V. K. LA MER. 1951. Kinetics of the Acid Decomposition of Sodium Thiosulfate in Dilute Solution. J. Am. Chem. Soc. **73** : 2050.
9. JABLCZYNSKI, C. K., and Z. WARSZAWSKA-RYTEL. 1926. La decomposition autocatalytique le l'acide hyposulfureux. Bull. soc. chim. France, 4 **39** : 409.
10. NEPTUNE, J. A., and E. L. KING. 1953. The Rate Law for the Reaction of Selenious Acid and Iodide Ion. J. Am. Chem. Soc. **75** : 3069.
11. PRAKKE, F., and E. STIASNY. 1933. Ueber Die Einwirkung von Thiosulfat auf Verdünnte Saurelösungen. Rec. Trav. Chim. **52** : 615.
12. SCHEFFER, J., and F. BOHN. 1929. Über den Zerfall der Thioschwefelsaure. Z. Anorg. Chem. **183** : 151.
13. ZAISER, E. M., and V. K. LA MER. 1948. The Kinetics of the Formation and Growth of Mono dispersed Sulfur Hydrosols. J. Colloid Sci. 3 : 571.

Cyclic Esters of Inorganic Acids. I.

ROBERT EARL DAVIS[1], Purdue University

The mechanisms of reaction of carboxylic esters have received great attention for many years. However, only within the past few years have systematic investigations been made of the mechanisms of reactions of other types of esters. Phosphate esters are of great interest because of their biochemical importance in metabolic processes involving ribonucleic acids, sugars and other hydroxylic compounds. Sulfate esters are rather common in living organisms, the most important esters being those of the mucopolysaccharides. Phenol detoxication in animal tissues is performed by sulfate esterification followed by urinary excretion.

The role of five-membered cyclic phosphate esters as intermediates in the hydrolysis of ribonucleic acids has recently been demonstrated.[6] The cyclic esters are readily hydrolyzed to the open-chain monoesters of phosphoric acid.[6,7] However, most diesters of phosphoric acid are relatively resistant to hydrolytic cleavage.[16]

The examination of the hydrolysis of potassium ethylene phosphate has been made by Westheimer.[17] The rate equation was first order in ester and first order in hydroxide ion. A positive salt effect was found and is expected for a reaction between two negatively charged ions. It was found that the five-membered ring ester is about 10^7 times more reactive than potassium dimethyl phosphate (Table I). This corresponds to difference in free energies of activation of about 9 kcal. The heat of alkaline saponification (Δ H) of the cyclic ester methyl ethylene phosphate[13] is –29.5 kcal/mole at 30°C. The open chain dimethyl β-hydroxyethyl phosphate has a Δ H of –21.9 kcal. Thus closure of the ring introduces kinetic acceleration of 8-9 kcal/mole and results in a thermodynamic strain of 7.6 $\pm$ 1.2 kcal (Table I).

The sulfate esters have been studied by Westheimer and coworkers.[15] In basic solution there is little kinetic acceleration upon closing the five-membered ring. However, the heat of hydrolysis increases by 7.7 $\pm$ 1.0 kcal. In base, the cleavages are usually C-O except for 15% of S-O cleavage in ethylene sulfate. In acidic solution only S-O cleavage is observed and the rates are nearly independent of the ring size.

The sulfite esters have been studied both by Bunton and coworkers[8,9,10] and by the present author. The present investigation has measured the very rapid rates of alkaline hydrolysis of ethylene sulfite and obtained more accurate data on dimethyl sulfite. The heats of solution and heats of hydrolysis have also been measured. The position of bond cleavage is in each case S-O.[8,9,10] The data have been presented in Tables I, II, and III.

---

1. The author wishes to thank Robert Wall and Thomas Kaiser for the calorimetric determinations. The invaluable discussions of this material with Prof. Frank Westheimer of Harvard is also gratefully appreciated. The initial phases of this work were begun under financial support from the National Institute of Health. The conclusion of the present study was made with support from The Walter Reed Army Institute of Research. The financial support of these organizations is gratefully appreciated.

TABLE I

Basic Hydrolysis of Esters

A. Phosphates		$T°C$	$k_2\ lm^{-1}sec^{-1}$	$\Delta H^{\ddagger}$ [a]	$\Delta S^{\ddagger}$ [b]	ΔH [c]
ethylene phosphate	d	25	4.6×10^{-4}			
dimethyl phosphate	d	25	3.0×10^{-11}			
		115	2.2×10^{-6}	27.5	−14	
		125	6.1×10^{-6}			
trimethyl	e	0.4	1.24×10^{-5}	15.2	−26	−20 ± 2
		35	3.39×10^{-4}			
dimethyl β-hydroxyethyl phosphate	f	30				−21.9 ± 0.4
methyl ethylene phosphate		30				−29.5 ± 0.6
B. Sulfates [g]		$T°C$	$k_2\ lm^{-1}sec^{-1}$	$\Delta H^{\ddagger}$	$\Delta S^{\ddagger}$	ΔH
ethylene		0.4	1.44×10^{-2}	16	−9	
		9.97	4.03×10^{-2}			
		30				−35.9 ± 0.7
trimethylene		30	2.73×10^{-3}			
		40	6.23×10^{-3}	15	−21	
dimethyl		9.97	2.14×10^{-3}	18	−8.5	
		30	1.60×10^{-2}			−28.2 ± 0.3
C. Sulfites						
ethylene		0	28			
		25	104	7.9	−23	−33.5 ± 0.5
trimethylene	h	0	8.0×10^{-2}			
		25	5.0×10^{-1}	11.3	−8	
dimethyl		0	2.33×10^{-2}			
		25	1.68×10^{-1}	12.2	−21	−32.8 ± 0.6

a—kcal/mole b—cal/mole degree c—kcal/mole d—Ref. 17 e—Ref. 3 f—Ref. 13 g—Ref. 15 h—Ref. 8, 9, 10

The problem can be stated by comparing the open chain derivative to the five-membered ring compound of both acid and basic solutions. The phosphates show tremendous kinetic acceleration and large thermodynamic strain. The sulfites show kinetic acceleration in basic solution but absolutely no thermodynamic strain. In acidic solution the reactivity pattern is reversed and the open chain compound is now reacting twenty times faster but there is still no thermodynamic strain.

The data have been interpreted in several manners. Westheimer has suggested the possible importance of 1,3-nonbonded interaction between the ring oxygen atoms.[10] This has been further developed by Bunton.[9] Westheimer also suggested the possible importance of the C-O-P dihedral

TABLE II
Acidic Hydrolysis

B. Sulfates [d]	$T°C$	k	$\Delta H^{\ddagger}$ [a]	$\Delta S^{\ddagger}$ [b]	ΔH [c]
ethylene	0.4	1.75×10^{-5} [e]			
	9.97	7.24×10^{-5} [e]	20.3	–5.4	
	30.0	7.6×10^{-4} [e]			
trimethylene	30.0	6.28×10^{-5} [e]			
	40.0	1.86×10^{-4} [e]	20	–12	
dimethyl	9.97	2.2×10^{-5} [e]			
	30	1.86×10^{-4} [e]	23	1.3	
C. Sulfites					
ethylene	0	4.1×10^{-7} [f]			
	25	1.01×10^{-5} [f]	20.2	–16	
	45 [g]	7.5×10^{-5} [f]			
	75 [g]	1.27×10^{-4} [f]			
trimethylene [g]	35	1.41×10^{-5}			
	60	1.57×10^{-4} [f]	20.2	–13	
diethyl [g]	0	1.98×10^{-3}	20.3	–8.2	
	25	3.36×10^{-3}			

a—kcal/mole b—cal/mole degree c—kcal/mole, calculated from basic reaction with heat of neutralization added d—Ref. 15 e—First order rate constant, independent of [H+], units sec^{-1} f—Second order rate constant, rate = k_2 [Ester] [H+], units lm^{-1} sec^{-1}. g—Ref. 8, 9, 10.

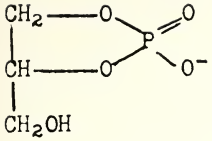
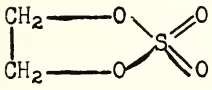
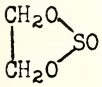
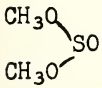
angle.[17] The first of these considerations has been examined in detail using the methods of molecular quantum mechanics. The model chosen for study is a two electron atom approaching another two electron atom. Slater nodeless AO orbitals have been used for this homopolar LCAO MO diatomic molecule. The screening factor has been kept constant. The energy difference between the ($\Psi a - \Psi b$) state and the ($\Psi a + \Psi b$) state has been used as an estimate of the repulsion forces. The data have been presented in Figs. 1 and 2.

Unfortunately, the bond angles and distances of these molecules are not known. It is known that ethylene sulfite is not planar. The NMR spectrum demonstrates that two of the four hydrogens are not equivalent with the others. At least one heavy atom is out of the plane of the ring. Indeed this is to be expected from sulfites as three-bonded sulfur forms a shallow pyramid.[1]

The calculations indicate that 1,3-nonbonded interactions may be of the order of magnitude to give rise to the effects observed. However, the effect is *not due entirely* to interaction between the two oxygen in the ring. Otherwise analogous reactivity patterns ought to be observed in the phosphates, phosphites, sulfates, sulfites, and carbonates. Most likely these interactions determine the dihedral angle. It is suggested that the presence of another oxygen atom about the surfur or phosphorus atom gives rise to the thermodynamic strain while the kinetic acceleration is

TABLE III

Position of Bond Cleavage in Base

	P-O		Ref. 3
$(CH_3O)_3PO$	P-O	(S_N2(P)	Ref. 3
	C-O S-O	85% 15%	Ref. 15
$(CH_3O)_2SO_2$	C-O	100%	Ref. 15
	S-O		Ref. 8
	S-O		Ref. 19

only observed if the nucleophilic attack is on the surfur or phosphorus rather than on the carbon atom.

Detailed kinetic, thermodynamic and O^{18} experiments are currently in progress on phosphite esters. The results will be reported elsewhere.

Experimental

Materials.

Ethylene sulfite was prepared in high yield from ethylene glycol and thionyl chloride in the manner described by Carlson and Cretcher.[11] The material was purified by repeated vacuum distillations, b. p. 85.0 – 85.6° at 50 mm, reported b. p. 86 – 88° at 52 mm.

Methyl sulfite was prepared from methanol and thionyl chloride, b. p. 126° at 758 mm.

The buffer solutions[12] were prepared from reagent grade salts. Conductivity water was used to prepare the solutions which were protected from atmospheric contamination.

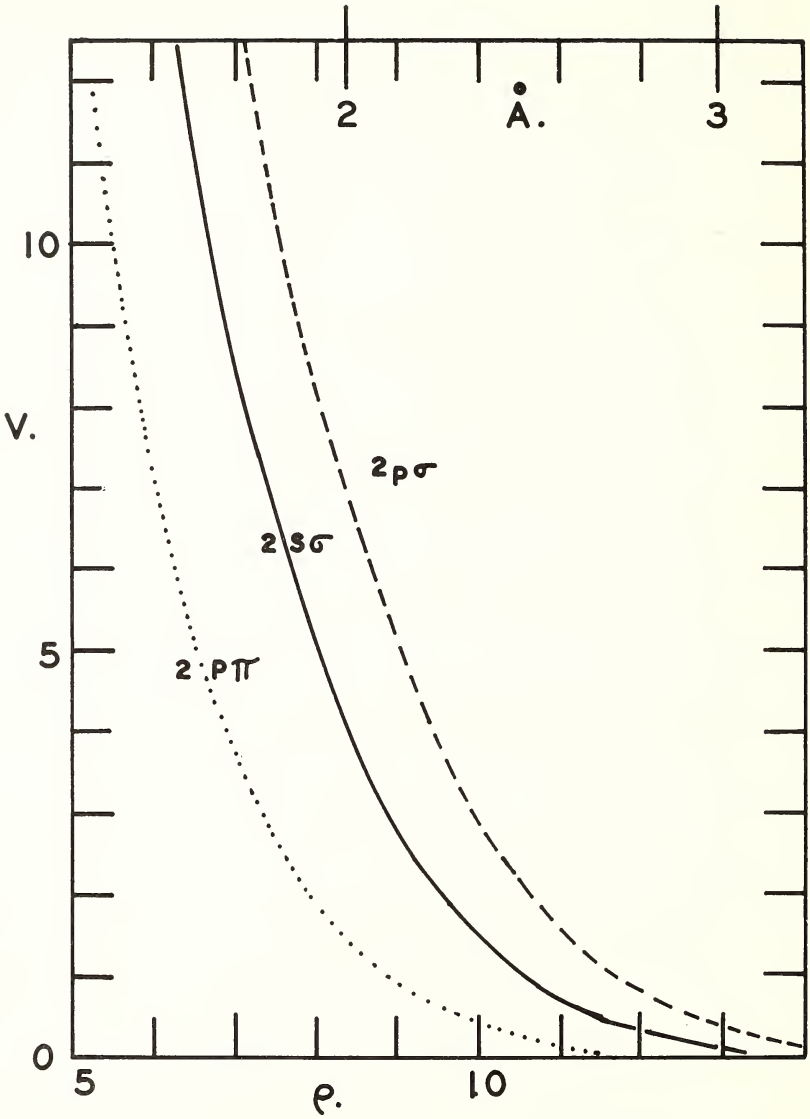


Fig. 1. Non bonded repulsion V. in kcal/mole versus distance between centers in Å for a four electron homopolar diatomic system. Calculated by the LCAO MO method.

Kinetic Methods.

During the basic hydrolysis of I or II, hydroxide ion is consumed and sulfite or bisulfite ion produced. Therefore, several methods have been used to study the reaction. All solutions were oxygen free and protected by pure nitrogen.

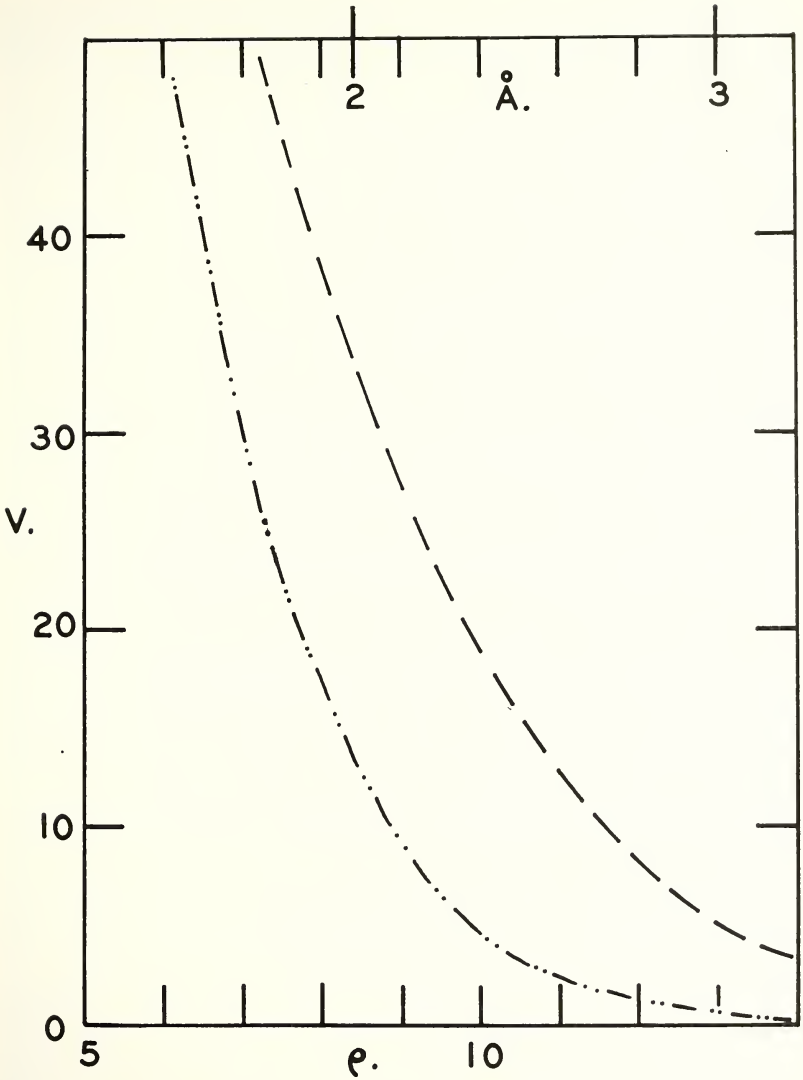


Fig. 2. Average potential energy V kcal/mole between two oxygen molecules. Dashed line represents the experimental curve of Amdur. The lower dash-dot line has been calculated using the data of Fig. 1 by a simple LCAO MO method.

The *amperometric method* (Method *A*) is based upon the electrolytic generation of hydroxide ion at an electrode and then measuring the steady-state hydroxide ion concentration with a pH meter.[18] A measured volume of an oxygen-free solution of ethylene sulfite (about 1 to 5 x 10^{-2} molar) in aqueous 0.1 molar potassium chloride is placed in a jacketed beaker. Through a large, tight-fitting rubber stopper is passed a centrally located

glass tube allowing nitrogen to be bubbled through the solution. The glass electrode and calomel electrode of a Beckman model G pH meter are placed near one side of the beaker. The generating electrode assembly is placed on the opposite side. The platinum cathode is placed directly into the solution. The anode compartment is constructed from a 10 x 1.5 cm. glass tube covered on one end by a Nepton CR-61 cation exchange membrane[14] cut in a circle. The membrane is slanted slightly to prevent gas bubbles from collecting under the anode and changing the electrode resistance. The glass tube is then filled with a slurry of Dowex 50, 50-100 mesh in 0.10 molar potassium chloride. A platinum wire inserted into this slurry forms the complete anode. The generating electrodes are very firmly mounted as this detail and a slanting membrane give good electrode stability. The cation ion resin and membrane thus prevent the diffusion of hydrogen ions into the solution. After each electrolysis the resins are reconverted into the potassium salt form. A voltage of one to sixteen volts D.C. is applied across the generating electrodes. An accurate D.C. milliameter in series with the cell measures the current which is between 2 and 40 ma. By adjusting the voltage slightly during electrolysis, a steady state is soon reached where both the pH and current remain constant. When a new voltage is selected a new pair of steady state values are recorded, yielding another estimate of the rate of reaction. The apparatus was checked at 25° by measuring the rate of ionization of nitroethane:[5,18,20] k_2 reported.

The *titrametric method* at static pH (method TS) for studying the reaction has been performed in the same jacketed beaker. The solution of ester (about 10^{-2} molar) is prepared in dilute buffer solution of a specific pH. The pH is then maintained constant by the addition of hydroxide from a micro buret driven by a "pH Stat." Two equivalents of base per mole of ester are consumed in a strictly first order reaction.

The *spectrophotometric-iodometric method* (method SI) involves the addition of a very dilute KI_3 (10^{-5} molar) to buffer solutions (pH 5.8-7.4) containing the ester. Only sulfite or bisulfite ion react with iodine and this reaction is very fast. Therefore, the rate of disappearance of the I_3^- color measured at 353 mμ in a Beckman DU spectrophotometer equals the rate of production of sulfur dioxide. As the ester concentration is 10^{-3} to 10^{-1} molar and the solution buffered, the disappearance of iodine occurs in a zero order reaction. The extinction coefficient of KI_3 has been found to be $2.60 \pm 0.06 \times 10^4$, in agreement with the value of 2.64×10^4 reported by Autrey and Connick[2] at 353 mμ in water. In neutral or mildly acidic solution, I_3^- is very stable. However, as the pH is raised about 9, hypoiodite is formed, with a decrease in the optical density of the solution.

The *indicator method* (method *I*) involves the addition of a pH indicator which changes color as a function of pH. Dilute solutions of ester (10^{-2} to 10^{-3} molar) and sodium hydroxide (10^{-3} molar) are rapidly mixed and the time of the color change of the indicator is measured visually with a stop watch. This time then gives a two-point kinetic curve: the initial time, $t = 0$, with known concentrations of reactants and the time, t, of the color change which occurs at a known pH. Indicators which are useful for this type of kinetic experiments are phenolphthalein (pK = 9.7),

m-cresol purple (pK = 8.3) and cresol red (pK = 8.1). If a rapid mixer is used and if a spectrophotometer is fitted to rapidly record the color change, the method becomes much more general and a useful tool to study rapid reactions with a pH change.

The more conventional technique was a *titrametric method* (method *T*) in deoxygenated aqueous buffer solutions based on the rate of appearance of sulfite ion. Aliquots of the solution were run into excess acidic KI_3 and back titrated with standard thiosulfate. This method has been used to study the alkaline hydrolysis of trimethylene sulfite.

Product Study.

The products of the basis hydrolysis of ethylene sulfite in sodium hydroxide are ethylene glycol and sodium sulfite. These compounds were determined to be the only products within 1-2% uncertainties of the analytical procedures of titration, spectral analysis and isolation. The pH profiles of solutions only partly hydrolyzed as determined by electrometric titration with dilute perchloric acid showed breaks for neutralization of the hydroxide ion, the sulfite and then the bisulfite ion. Derivative curves showed no other component present to within 1–2% uncertainty. Thus no evidence has been obtained for the accumulation of mono esters, $ROSO_2H$ or $ROSO_2^-$.

Likewise the sole products of hydrolysis of dimethyl sulfite are methanol and sodium sulfite.

Temperature Control.

For methods *A* and *TS* water from a constant temperature bath (± 0.01°) was circulated rapidly through the jacketed beaker. For method *SI* a Westheimer brass jacket[4] was used as the cell compartment of the DU spectrophotometer. Circulating water maintained the temperature to ± 0.02. All temperatures were referred to NBS certified thermometers. Method *I* was studied in an ice bath at ± 0.005°. Method *T* was studied in Pyrex volumetric flasks, thermostated under N_2 in water baths ± 0.01°.

Thermochemistry.

The heats of hydrolysis were determined in a calorimeter constructed from a small Dewar flask and Beckman thermometer within a submergable copper can. The calorimeter had a thermal leak coefficient of 0.0043°/min. Calibration was performed using the heat of dilution of sulfuric acid and electrical measurements. The reproducibility was ± 1.5%. An ampule of about 0.1 gram of the ester was crushed under 50.00 ml of 0.1 N sodium hydoxide at 30.00°. The heat of solution of each ester was measured in pH 7 phosphate buffer (0.1 M) at 30.0°. The results were averaged over several runs.

$$(C_2H_4SO_3) \rightarrow (C_2H_4SO_3)_{\text{aq. soln. (0.02M)}} \quad \Delta H = +0.64 \pm 0.07 \text{ kcal.}$$

$$(C_2H_6SO_3) \rightarrow (C_2H_6SO_5)_{\text{0.02M aq. soln.}} \quad \Delta H = -0.17 \pm 0.02 \text{ kcal.}$$

$$(C_2H_4SO_3) + 2NaOH_{(0.1M)} \rightarrow C_2H_4(OH)_{2(aq.)} + Na_2SO_{3(aq.)} \quad \Delta H = -33.5 \pm 0.5 \text{ kcal.}$$

$$(C_2H_6SO_3)_{\text{0.02 M aq.}} + 2NaOH_{0.1M} \rightarrow 2\ CH_3OH_{aq.} + Na_2SO_{3\ aq.} \quad \Delta H = -32.8 \pm 0.6 \text{ kcal.}$$

Equilibria Studies.

The equilibrium between ethylene sulfite, methanol, dimethyl sulfite and ethylene glycol has been measured using VPC analysis of the materials on a Perkin-Elmer 2 meter, R column at 100°.

Literature Cited

1. ABRAHAMS, S. C. 1956. The Stereochemistry of Sub-Group VI B of the Periodic Table. Quart. Rev. **10**: 424.
2. AUTREY, A. D., and R. CONNICK. 1951. The Absorption Spectra of I_2, I_3^-, I^-, IO_3^-, $S_4O_6^{-2}$ and $S_2O_3^{-2}$. Heat of the Reaction $I_3^- = I_2 + I^-$. J. Am. Chem. Soc. **73**: 1842.
3. BARNARD, P. W. C., *et al.* 1955. The Hydrolysis of Organic Phosphates. Chem. and Ind. **1955**: 760.
4. BARTLETT, P. D., and R. E. DAVIS. 1958. Reactions of Element Sulfur. II. The Reaction of Alkali Cyanides with Sulfur, and Some Single-Sulfur Transfer Reactions. J. Am. Chem. Soc. **80**: 2513.
5. BELL, R. P., and J. C. CLURIE 1952. Proc. Roy. Soc. London. *A***212**: 16.
6. BROWN, D. M., and A. R. TODD. 1952. Nucleotides. Part X. Some Observations on the Structure and Chemical Behavior of the Nucleic Acids. J. Chem. Soc. **1952**: 52.
7. BROWN, D. M., D. I. MAGRATH, and A. R. TODD. 1952. Nucleotides. Part XII. The Preparation of Cyclic 2′ 3′ - Phosphates of Adenosine, Cytidine, and Uridine. J. Chem. Soc. **1952**: 2708.
8. BUNTON, C. A., *et al.*, 1956. The Mechanisms of Hydrolysis of Cyclic Sulphites. Chem. and Ind. **1956**: 490.
9. BUNTON, C. A., *et al.*, 1958. Nucleophilic Displacements in Organic Sulfites. Parts I, II, III, and IV. J. Chem. Soc. **1958**: 4751, 4754, 4761, 4766.
10. BUNTON, C. A., *et al.*, 1950. Nucleophilic Displacements in Organic Sulfites. Part VI. J. Chem. Soc. **1960**: 37.
11. CARLSON, W. W., and L. H. CRETCHER. 1947. Hydroxyalkylatron with Cyclic Alkylene Esters. I. Synthesis of Hydroxyethylapocupreine. J. Am. Chem. Soc. **69**: 1953.
12. CLARK, W. M. 1928. The Determination of Hydrogen Ions. 3rd. Edition, Williams and Wilkins. Baltimore.
13. COX, J. R., R. E. WALL, and F. H. WESTHEIMER. 1959. Thermochemical Demonstration of Strain in a Cyclic Phosphate. Chem. and Ind. **1959**: 929.
14. IONICS, INC. 152 Sixth Street. Cambridge, Mass.
15. KAISER, T. 1959. Thesis. Harvard.
16. KOSOLAPOFF, G. M. 1950. Organo phosphorous compounds. John Wiley and Sons. New York. Chapter 9.
17. KUMAMOTO, J., J. R. COX, and F. H. WESTHEIMER. 1956. Barium Ethylene Phosphate. J. Am. Chem. Soc. **78**: 4858.
18. PEARSON, R. G., and L. H. PIETTE. 1954. A Simple Steady State Method for Obtaining Rates of Rapid Reactions. J. Am. Chem. Soc. **76**: 3087.
19. WESTHEIMER, F. H. 1957. Studies of the Solvolysis of Some Phosphate Esters. Chem. Soc. Special Publ. No. 8. p. 1.
20. YOUNG, J. A., and R. J. ZETA. 1958. An Amperometric-Kinetic Experiment Emphasizing the Importance of Enor Treatment. J. Chem. Ed. **35**: 146.

Reduction Studies of Various Substituted Carbostyrils

D. J. Cook and Richard N. Pierce, DePauw University

This study was undertaken to determine the value of complex metal hydrides as reducing agents for certain functional groups when they are a part of the carbostyril ring system. Sodium borohydride has been found capable of reducing 4-formylcarbostyrils to the corresponding alcohols, carbostyrilcarboxaldehyde anils to the corresponding secondary amines and several carbostyrilnitroalkenes to the carbostyrilnitroalkanes without attacking the heterocyclic or homocyclic rings of the carbostyril.

The ease of oxidation of 1,4-dimethylcarbostyril and 4-methylcarbostyril to the corresponding 4-formylcarbostyrils with selenium dioxide has been demonstrated in past work. (1) (2) The 1-methyl-4-formylcarbostyril has previously been converted to the alcohol by reduction with aluminum isopropoxide. (1) In this study the reduction was carried out with sodium borohydride in methanol in a much more efficient manner. When 4-formylcarbostyril was reduced in the same manner, a 92% yield of 4-hydroxymethylcarbostyril was obtained.

Several anils of the 1-methyl-4-formylcarbostyril have been prepared by Cook and Flanders. (3) When 1-methyl-4-formylcarbostyril-p-phenylanil was treated with sodium borohydride, an 85% yield of 1-methyl-4-(p-biphenylaminomethyl)carbostyril was obtained.

Evidence from the infrared absorption studies of this reduction shows that the anil was converted to the secondary amine without attack on the ring. An absorption spectra of the reduced product revealed the presence of the –NH– stretching band at 3500 cm^{-1} and the –NH– deformation band at 1530 cm^{-1}. Evidence is also found from the spectra that no reduction took place in the rings of this compound. A moderate band at 876 cm^{-1} is related to the one out-of-plane hydrogen of the heterocyclic ring while a strong band at 757 cm^{-1} is indicative of the four adjacent hydrogens in the homocyclic ring. A moderate band at 839 cm^{-1} is due to the two adjacent hydrogens in the anil phenyl ring and two strong bands at 771 cm^{-1} and 707 cm^{-1} indicates the monosubstituted phenyl ring on the para position of the anil ring. In a similar type of reduction 1-methyl-4-(p-(diethylamino)phenylaminomethyl)carbostyril was prepared in 53% yield from 1-methyl-4-formylcarbostyril-p-diethylaminoanil.

1-(1'-Methyl-4'-carbostyril)-2-nitroethanol and 1-(1'-methyl-4'-carbostyril)-2-nitropropanol have been previously prepared by Cook and Stamper. (1) The present method describes an improved method of preparation of these compounds. These alcohols were converted to 1-(1'-methyl-4'-carbostyril)-2-nitroethene and 1-(1'-methyl-4'-carbostyril)-2-nitro-1-propene by dehydration with acetic anhydride in pyridine. The method of Schecter, Ley and Roberson (4) was used to reduce the olefinic bond of these compounds to the saturated nitro derivatives. 1-(1'-Methyl-4'-carbostyril)-2-nitroethane was obtained in 16% yield and had a melting point of 139-140.5° while 1-(1'-methyl-4'-carbostyril)-2-nitropropane was recovered in 15% yield and had a melting point of 115.5-116.5°.

Several attempts were made to carry out reductions on the functional groups attached to the carbostyril ring using lithium aluminumhydride.

In each case the lactam group of the heterocyclic ring was also attacked resulting in a mixture of products which were not identified.

Experimental

1-Methyl-4-formylcarbostyril was prepared by the method of Cook and Stamper (1) and was found to melt at 179-180°.

4-Formylcarbostyril. This compound was prepared as described by Yunghans (2) but has not been previously reported in the literature. Ten grams (0.063 moles) of 4-methylcarbostyril was added to 100 ml. of diphenyl ether and heated to 185°. While the solution was stirred, 7.77 g. (0.07 moles) of selenium dioxide was added portionwise. Stirring and heating was continued for two hours. The hot diphenyl ether was decanted from the selenium and diluted with 200 ml. of ligroin (b. p. 100-120°). Upon cooling in ice, a light yellow solid precipitated. When recrystallized from a benzene-ethanol mixture, 8 g. (72.7%) of light yellow crystals, m.p. 267°, was obtained.

Anal. Calcd. for $C_{10}H_7O_2N$: N, 8.09%. Found: N, 8.21%.

1-Methyl-4-hydroxymethylcarbostyril. Four grams (0.026 moles) of 1-methyl-4-formylcarbostyril was dissolved in 100 ml. of methanol and cooled in an ice-bath. Four grams of sodium borohydride (0.106 moles) was added to the solution in small portions. The reaction mixture was shaken throughout the addition. When the reaction had subsided, it was hydrolyzed with 10% hydrochloric acid. A white powder was recovered from the solution upon evaporation. Recrystallization of this product from 130 ml. of hot water gave 4.4 grams (97.7%) of the desired alcohol with a m.p. of 185-187.5°. Cook and Stamper reported a m.p. of 187-188°.

4-Hydroxymethylcarbostyril. Three grams of 4-formylcarbostyril (0.019 moles) was dissolved in 50 ml. of methanol and with vigorous stirring was reduced with 1.0 g. of sodium borohydride. After hydrolysis with 10% hydrochloric acid and evaporation to dryness, 3.2 g. of a white powder was obtained. Upon recrystallization from ethanol, 2.8 g. (92%) of the product melting at 271-272° was obtained. Sorter has reported a m.p. of 265°.

Infrared Absorption Bands (in Nujol): 3350 cm^{-1} (m—broad), 1650 (s), 1093 (s), 857 (m) and 753 (s).

1-Methyl-4-formylcarbostyril-p-phenylanil. This compound was prepared by the method of Cook and Flanders (3) from the 1-methyl-4-formylcarbostyril and p-phenylaniline. When crystallized from ethanol and a small amount of water, yellow crystals melting at 156-157° (dec.) were obtained.

Anal. Calcd. for $C_{23}H_{18}N_2O$: N, 8.28%. Found: N, 8.27%.

1-Methyl-4-formylcarbostyril-p-diethylaminoanil. This compound was prepared as described by Cook and Flanders. (3) The melting point was 171-172°.

1-Methyl-4-(p-biphenylaminomethyl)carbostyril. Four grams (0.0123 moles) of 1-methyl-4-formylcarbostyril-p-phenylanil was placed in 80 ml. of methanol and 0.6 g. (0.013 moles) of sodium borohydride was added to

the solution. After the initial reaction had subsided, the mixture was heated on the steam bath for five minutes. During the reaction a white precipitate formed and with the addition of 20 ml. of water to the solution, the product was completely precipitated. The product was washed with water, dried, and then dissolved in sufficient hot benzene. The product from the benzene weighed 3.6 g. (85.7%) and melted at 209-210°.

Anal. Calcd. for $C_{23}H_{20}N_2O$: N, 8.23%. Found: N, 8.19%.

Infrared Absorption Bands (in Nujol) 3500cm^{-1} (w), 1660 (s), 1530 (m), 876 (m), 839 (m), 757 (s), 771 and 707 (s).

A *picrate* of this compound was obtained and found to melt at 166-167.5°.

Anal. Calcd. for $C_{29}H_{23}N_5O_8$: N, 12.30% Found: N, 12.41%

1-Methyl-4-(p-(diethylamino)phenylaminomethyl)carbostyril. One gram (0.0029 moles) of 1-methyl-4-formylcarbostyril-p-diethylaminoaril was dissolved in 20 ml. of methanol. In a manner similar to the preparation of 1-methyl-4-biphenylaminomethyl)carbostyril, 0.75 g. of sodium borohydride (0.029 moles) was added rapidly to the methanol solution. When the reaction was complete and the product recovered, recrystallization from ethanol gave 0.58 g. of a substance melting at 160-161°. The yield was 54%.

Anal. Calcd. for $C_{21}H_{25}N_3O$: N, 12.54% Found: N, 12.70%

1-(1'-Methyl-4'-carbostyril)-2-nitroethanol. Twenty grams (0.106 moles) of 1-methyl-4-formylcarbostyril was dissolved in 500 ml. of boiling ethanol. A mixture of 40 ml. of nitromethane and 8 ml. of diethylamine was added to the boiling solution. After standing for 4-5 hours, the product was formed and recovered from the solution by filtration. A yield of 17 g. (64%) with a m.p. of 175-177° was recovered. When this product was recrystallized from ethanol the m.p. was found to be 184-184.5° (dec.). A previous reported m.p. for this compound on a Fisher-Johns melting block was 168-170°. When a sample of this compound was melted on the Fisher-Johns block, it was found to melt at 172-173° (dec.).

Infrared Absorption Bands (in Nujol): 3360 cm^{-1} (m), 1645 (s), 1580(s), 1550 (s), 1325 (w), 1278 (w), 1115 (m), 1055 (m), 887 (m), and 761 (s).

1-(1'-Methyl-4'-carbostyril)-2-nitropropanol. The condensation of 1-methyl-4-formylcarbostyril and nitroethane was carried out in the same manner as described by Cook and Stamper. (1) The product melted at 174-176° and was obtained in 65% yield.

1-(1'-Methyl-4'-carbostyril)-2-nitroethene. Ten grams (0.04 moles) of 1-(1'-methyl-4'-carbostyril)-2-nitroethanol was dissolved in 100 ml. of warm pyridine and arranged for reflux. Sixty milliliters of acetic anhydride was added to the mixture and brought to boiling for three minutes. Upon cooling the solution, long orange-yellow needles precipitated. The mixture was poured into 350 ml. of ice water and stirred. The precipitate was collected and found to melt at 191-197°. After recrystallization from acetone, the product melted at 215-217° (dec.). The yield was 8.5 g. (91.4%).

Anal. Calcd. for $C_{12}H_{10}N_2O_3$: N, 12.17% Found: N, 12.24%

1-(1'-Methyl-4'-carbostyril)-2-nitro-1-propene. In a manner similar to the preceding preparation, 2.5 g. of the 1-(1'-methyl-4'-carbostyril)-2-nitropropanol was converted to the olefin. The precipitate obtained weighed 2.0 g. (86%) and melted at 181-182°.

Anal. Calcd. for $C_{13}H_{12}N_2O_3$: N, 11.48% Found: N, 11.55%

Infrared Absorption Bands (in Nujol): 1675 cm^{-1} (s), 1600 (m), 1525 (m), 1328-1322 (m), 929 (w), 865 (w) and 758 (s).

1-(1'-Methyl-4'-carbostyril)-2-nitroethane. Nine grams (0.039 moles) of 1-(1'-methyl-4'-carbostyril)-2-nitroethene was dissolved in 1 liter of methanol and cooled in ice. With stirring vigorously, 10 g. (0.264 moles) of sodium borohydride was added to the solution. After the reaction was complete, the solution was neutralized with 10% hydrochloric acid. The solution changed from a red color back to a yellow color upon acidification. The solution was then concentrated to 75 ml. by heating under a vacuum and filtered hot to remove a small amount of tar. After cooling 3 g. of a tan precipitate, m.p. 130-137.5°, was obtained. The precipitate was recrystallized from water. One-half gram (16.5%) of the pure product, m.p. 139-140.5°, was obtained.

Anal. Calcd. for $C_{12}H_{12}N_2O_3$: N, 12.06% Found: 12.09%

Molecular Weight Calculated 232.2 Found: 234

Infrared Absorption Bands (in $CHCl_3$ against a $CHCl_3$ reference cell) 3080 cm^{-1} (w), 1665 (s), 1600 and 1565 (s), 1460 (m), 1380 (m), 1330 (w) and 887 (w).

1-(1'-Methyl-4'-carbostyril)-2-nitropropane. One gram of 1-(1'-methyl-4'-carbostyril)-2-nitro-1-propene was placed in 50 ml. of methanol and reduced with sodium borohydride in much the same manner as the preceding preparation. After recrystallization of the product from alcohol, 0.15 g. (14.9%) of the pure substance was obtained. It melted at 115-116.5° (dec.).

Anal. Calcd. for $C_{13}H_{14}N_2O_3$: N, 11.38% Found: N, 11.25%

Molecular Weight Calculated: 246.2 Found: 244

Literature Cited

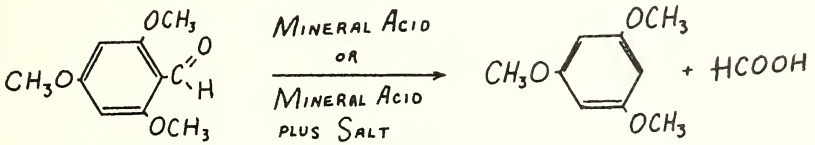
1. COOK, D. J. and STAMPER, M. 1947. J. Am. Chem. Soc. **69**: 1467.
2. YUNGHANS, R. S. 1952. *Studies in the Chemistry of N-Substituted Pyridones and Quinolones.* M. A. Thesis, DePauw University. p. 59.
3. COOK, D. J. and FLANDERS, H. 1950. Proc. Ind. Acad. Sci. **60**: 138.
4. SCHECHTER, H. I., LEY, D. B. and ROBERSON, R. B. 1956. J. Am. Chem. Soc. **78**: 4984.
5. SORTER, P. F. 1956. *Bromination Studies of Alkyl Substituted 2-Quinolones and 2-Pyridones.* M. A. Thesis DePauw University. p. 47.

Acid-Catalyzed Decarbonylation of 2,4,6-Trimethoxybenzaldehyde. An Anomalous Oxidation Reaction.[1]

Howard Burkett and Ronald Bowen, DePauw University

Introduction

Normally when 2,4,6-trimethoxybenzaldehyde at ca. 10^{-5} to 10^{-4} molar concentration is treated with mineral acids and mineral acid salts, the only product obtained is the decarbonylation product, 1,3,5-trimethoxybenzene, or at higher acid concentrations, phloroglucinol by demethylation of the initial product (1).



Discussion

Using perchloric acid-sodium perchlorate solutions, the sequence of changes of the ultraviolet spectrum were different from those otherwise observed, and the reaction mixture was noticeably yellow. Although decarbonylation proceeded at a comparable rate with or without the added sodium perchlorate (as indicated by following the disappearance of the 315-320 mμ absorption in the ultraviolet spectrum), the final spectra were dissimilar. The most distinctive feature was the development of a strong absorption band at 288-292 mμ. (See Fig. 1)

Similar final spectra were obtained when 1,3,5-trimethoxybenzene and phloroglucinol were substituted for 2,4,6-trimethoxybenzaldehyde, although there was a slight shift of the 288-292 mμ absorption band to a shorter wavelength in the latter case.

In order to investigate the role played by sodium perchlorate, 1,3,5-trimethoxybenzene was treated with solutions of 5.02 molar perchloric acid which were 1.00 molar in sodium chloride, 0.50 molar in magnesium perchlorate, and with a solution which was 6.00 molar in sodium perchlorate. The solution of perchloric acid-magnesium perchlorate gave results identical to those obtained using perchloric acid-sodium perchlorate; the solution of perchloric acid-sodium chloride and the solution of

1. This research was supported by a grant from the Petroleum Research Fund administered by the American Chemical Society and grateful acknowledgement is hereby made to donors.

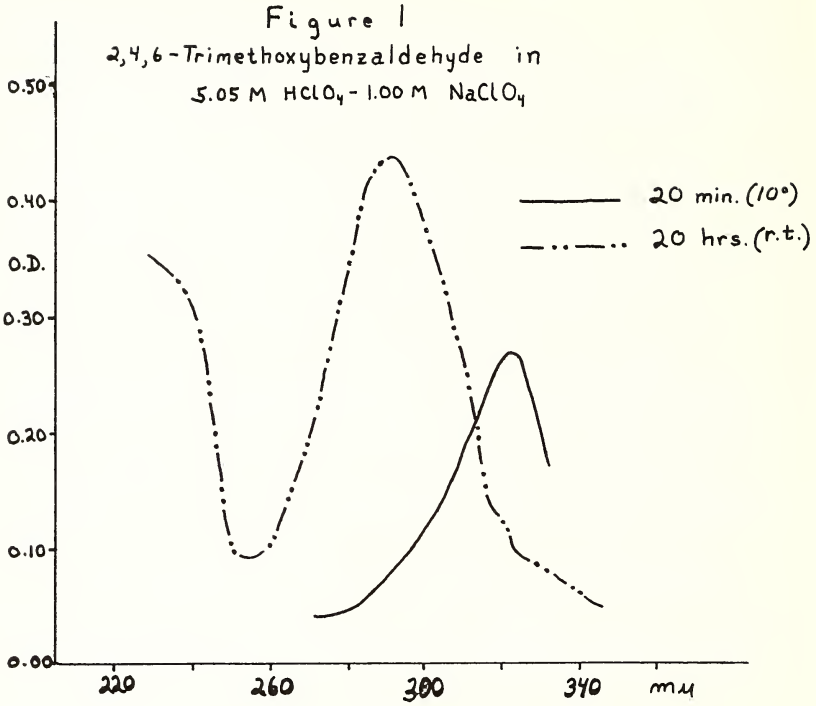


Figure 1

1. The product prepared by the published method (2) was purified by chromatography over alumina using chloroform as the solvent. The melting point of the best sample was 255-256°. The reported melting point is 253-254.5°.

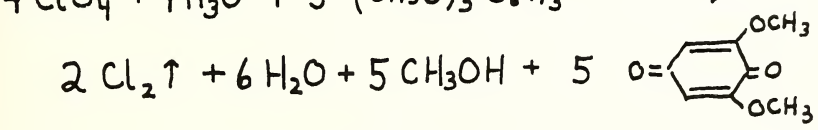
sodium perchlorate gave no absorption band in the 288-292 mμ region of the ultraviolet spectrum.

Among the possible compounds which might be producing the 288-292 mμ absorption band, an oxidation product was considered, the most probable being 2,6-dimethoxybenzoquinone-1,4. An authentic sample of this compound was prepared by a published method (2). The ultraviolet spectrum of this yellow compound in various perchloric acid-perchlorate sale and perchloric acid solutions was identical to the final spectrum observed when 1,3,5-trimethoxybenzene or 2,4,6-trimethoxybenzaldehyde were treated with perchloric acid-perchlorate salt solutions. In addition to this spectral evidence, the oxidation product from the perchloric acid-sodium perchlorate treatment was identified by isolation.

Since it seemed possible that a contaminant in the sodium perchlorate was responsible for the oxidation, several commercial samples of sodium perchlorate were tried. All gave oxidation of 1,3,5-trimethoxybenzene to the quinone. In addition, a perchloric acid-sodium perchlorate solution was prepared from concentrated stock solutions of perchloric acid and sodium hydroxide. The final solution was 3.50 molar in perchloric acid

and 4.36 molar in sodium perchlorate. When a sample of 1,3,5-trimethoxybenzene was treated with this solution, no reaction took place even after three days at room temperature or after four hours at 90°. Addition of a small amount of potassium chlorate caused the oxidation to proceed at a comparable rate to those observed in previous experiments. In 8.00 molar perchloric acid which was $2x10^{-4}$ molar in potassium chlorate, the oxidation proceeded at a rate too fast to be measured at 30°.

In order to determine the stoichiometry of the reaction, weighed amounts of 1,3,5-trimethoxybenzene were added to a solution of 8.00 molar perchloric acid which was $2.9x10^{-3}$ molar in potassium chlorate and the optical density at 290 mμ was determined after each addition. The reaction stopped corresponding to a 5:4 molar ratio of the trimethoxybenzene to potassium chlorate. A balanced equation corresponding to this ratio is shown below. The odor of chlorine was noted in those reactions producing oxidation.



Experimental

Materials

The 2,4,6-trimethoxybenzaldehyle, prepared by a known method and recrystallized several times from ethanol or water, melted at 117.5-118° (3).

Perchloric acid solutions were made by appropriate dilution of analytical reagent grade concentrated acid. Acid concentration was determined by titration with sodium hydroxide. Reagent grade salts were used and their concentrations were determined by calculation.

Spectra

The ultraviolet absorption spectra were obtained on a Beckmann Model DU quartz spectrophotometer. The temperature was regulated to 30.00° ± 003°.

Isolation of 2,6-Dimethoxybenzoquinone-1,4

To 20 mg. of 2,4,6-trimethoxybenzaldehyde was added 40 ml of a solution which was 5.05 molar in perchloric acid and 2.00 molar in sodium perchlorate (analytical reagent grade, anhydrous). The mixture was warmed to 40° with shaking until the aldehyde was all dissolved and was maintained at this temperature for one hour. After dilution with 80 ml of water and cooling, the resulting yellow solution was extracted with chloroform in several portions. The yellow chloroform solution was dried over magnesium sulfate and evaporated to dryness. The yellow solid was washed three times with boiling ethanol. The insoluble residue, yellow needles, melted at 253-254°. A mixed melting point with authentic 2,6-dimethoxybenzoquinone-1,4 gave a melting point of 254-255°.[1] The infrared spectra of the two materials were identical.

Stoichiometry

To 25.00 ml of an 8.00 molar solution of perchloric acid was added 0.908 mg. of potassium chlorate and 0.369 mg. of 1,3,5-trimethoxybenzene. The optical density was measured at 290 mμ and was found to be 0.559. Similarly 0.710 and 1.045 mg. samples of 1,3,5-trimethoxybenzene were added giving optical densities of 0.673 and 0.671 respectively.

From this data the molar ratio of 1,3,5-trimethoxybenzene to potassium chlorate was calculated to be 5.00:4.09.

Literature Cited

1. BURKETT, HOWADD, SCHUBERT, W. M., SCHULTZ, FRED, MURPHY, RICHARD B., and TALBOTT, RICHARD. 1959. Acid-Base Catalysis in Non-dilute Aqueous Acid. The "Decarbonylation" of 2,4,6-Trimethoxybenzaldehyde. Jour. Am. Chem. Soc. **81**: 3923.

2. CIAMICIAN, G. and SILBER, P. 1893. Ueber das Symmetrische Dimethoxychinon. Berichte **26**: 784.

3. HERZING, J. and WENZEL, F. 1903. Uber Phloroglucintrimethylatheraldehyde (2, 4,6-Trimethyl-Phlorotriol-5-al) und einige Derivate desselben von Dr. H. Gehringer. Monatsh. chemie **24**: 866.

A Preliminary Study of Differential Thermal Analysis, Conductance and Cryoscopic Behavior of Dimethyl Sulfoxide Complexes

E. Eugene Weaver and William Keim, Wabash College

Introduction

When dimethyl sulfoxide (DMSO) became commercially available, several of its physical properties immediately suggested its desirability as a solvent for inorganic compounds. The compound's liquid range (18.5-189°C), moderate viscosity (1.98 centipoise) and high dielectric constant (47) are most important among these properties. Also the convenient freezing point of DMSO (18.45°C) suggested possible utility as a solvent for cryoscopic measurements.

Erhard Saettler[12], working in this laboratory on a senior project, found that many inorganic salts are quite soluble in DMSO and when these solutions are cooled or the excess solvent removed by pumping, solid complexes or solvates are formed which are analogous to hydrates. These compounds first reported by Saettler are listed in Table 1.

TABLE 1

Analysis of Complexes

Formula	Color	% DMSO Theory	% DMSO Found	% Metal Theory	% Metal Found
$Co(NO_3)_2 \cdot 4DMSO$	Magenta	63.1	64.1	11.9	11.7
$CoCl_2 \cdot 3DMSO$	Deep Blue	64.4	64.4	16.2	16.3
$NiCl_2 \cdot 3DMSO$	Blue-green	64.4	63.9	16.1	16.0
$FeCl_3 \cdot 3DMSO$	Yellow	59.1	58.8	14.1	14.5
$Cu(OAc)_2 \cdot DMSO$	Blue-green	30.1	30.2	24.5	24.2
$CuCl_2 \cdot 2DMSO$	Chartreuse	53.8	53.7	21.9	21.1

Since this time, DMSO has been used as a solvent in experiments in the Physical Chemistry laboratory at Wabash College. Experiments where DMSO has been used as a solvent instead of water are: cryoscopic measurements, conductance, polarimetry, spectrophotometry in visible and ultraviolet regions, phase diagrams, and electrochemical cells. It has also been given to students as an unknown for determination of dielectric constant.

Recently, Cotton and Francis[2] have reported the preparation and characterization of 35 complexes containing DMSO. Also, Sears, Lester and Dawson[13] have reported conductance measurements of uni-univalent electrolytes in DMSO. The Cotton and Francis report includes four of the six complexes described by Saettler. In the case of $FeCl_3$, Cotton and Francis report $FeCl_3 \cdot 2DMSO$ while in this laboratory $FeCl_3 \cdot 3DMSO$ was found. Cotton and Francis also propose that $CoCl_2 \cdot 3DMSO$ and $NiCl_2 \cdot$

3DHSO have the following structure in the solid state, $[M(DMSO)_6]^{2+}$ $[MCl_4]^{2-}$.

The first objective of this research has been to use differential thermal analysis to determine whether these complexes lose DMSO stepwise in the manner of many hydrates and thus explain the two complexes reported for $FeCl_3$. The second objective has been to use conductance and cryoscopic measurements to determine the nature of the ions in solution and to compare with the structures suggested by Cotton and Francis for the solids.

Acknowledgement should be made for the exploratory experiments carried out by many students in connection with their Physical Chemistry laboratory. The authors wish to express appreciation to DuPont and Company for financial assistance during the latter stages of the research.

Experimental

1. Preparation of Complexes—Dimethyl sulfoxide was initially obtained from Stepan Chemical Company, and more recently from Crown Zellerbach Corporation. The DMSO was used as received in the preparation of the complexes. The small amount of water in the DMSO or the presence of water in the hydrated salts used had no effect on the composition of the complexes. The complexes listed in Table 1 were prepared by dissolving the corresponding reagent grade hydrated salt in DMSO at 60-80°C and cooling until the solid complex separated out. If no solid was obtained by cooling, the excess solvent was removed by evacuation. In either case the solids obtained were pumped on in a vacuum dessicator until free of excess DMSO. In the case of $Co(NO_3)_2 \cdot 4DMSO$, acetone was used to an advantage as a solvent for recrystallization. Most of the complexes are hygroscopic and as many operations as possible were carried out in a dessicated glove box.

2. Analysis—The complexes were analyzed for DMSO and the metal constituent. DMSO was determined by the method of Douglas[4]. Cobalt, nickel and copper were analyzed by standard electrolytic methods. Iron was analyzed by standard gravimetric procedures. The results are tabulated in Table 2.

3. Differential Thermal Analysis Apparatus and Procedure—A simple DTA apparatus utilizing thermistors as the temperature sensing elements was designed and built. The apparatus consisted of an aluminum block 2 inches in diameter containing two holes for the sample tubes and a third for the thermocouple, all drilled from the top. The sample tubes were made from ¼ inch diameter aluminum tube and were secured to a cap which insured reproducible positioning of the sample tubes within the block. Into one sample tube was placed 120 mg of calcined Al_2O_3 (Merck Reagent) and in the second tube, 60 mg of the sample and 60 mg of Al_2O_3 thoroughly mixed. The matched pair of Fenwal No. GA51P2 thermistors (100,000 ohms at 25°C) were inserted to a fixed depth in the sample and blank. The thermistors were cemented with "plastic aluminum" to a pyrex tube which fitted snugly over the glass body of the thermistor. Leads of No. 26 copper wire were welded to the thermistor leads [15], and brought out through the pyrex tube. The assembled unit was placed in a crucible furnace, and the heating rate of the aluminum block controlled by the

TABLE 2

Equivalent Conductances of Complexes in DMSO

	$Cx10^4$	Λ		$Cx10^4$	Λ		$Cx10^4$	Λ
(a)	$Co(NO_3)_2 \cdot 4DMSO$		(b)	$CoCl_2 \cdot 3DMSO$		(c)	$NiCl_2 \cdot 3DMSO$	
	Eq. wt. = 495.49/2			Eq. wt. = 364.25/2			Eq. wt. = 363.99/2	
	7.21	39.89		7.21	35.47		11.13	34.92
	14.41	37.83		11.96	28.79		22.25	31.51
	28.82	35.63		14.41	28.44		31.43	29.99
	61.64	34.42		23.91	22.06		44.51	28.39
				28.83	21.11		62.86	26.80
				47.82	16.52			
(d)	$FeCl_3 \cdot 3DMSO$		(e)	$CuCl_2 \cdot 2DMSO$		(f)	$Cu(OAc)_2 \cdot DMSO$	
	Eq. wt. = 396.61/2			Eq. wt. = 290.75			Specific conductance = 1.8×10^{-6}	
	10.79	23.78		4.75	32.09		$ohm^{-1}\ cm^{-1}$	
	21.58	19.95		9.49	26.93			
	29.40	19.56		18.99	22.26			
	43.17	17.13		25.11	20.09			
	58.80	16.86		50.22	15.17			
	117.60	14.93						
(g)	KI		(h)	$CaCl_2$				
	17.17	36.01		4.78	40.10			
	34.34	34.70		9.55	37.01			
	68.67	33.56		19.10	33.45			
				38.20	28.81			
				76.40	25.51			

setting of a Powerstat. The difference between the heating rates of the blank and the sample was followed by making the thermistor's legs of a Wheatstone bridge[11]. The unbalance of the bridge was recorded by a Varian G10 recorder with 100 mv range and chart speed of 16 in./hr. The tracings as obtained are shown in Figures 1 and 2. The temperatures indicated on the individual traces were obtained by a 15 mv Brown Electronik recorder and a copper-constantan thermocouple. The samples were heated to 300°C.

4. Cryoscopic Apparatus and Procedure—The neck of a 50 ml Erlenmeyer flask was modified by sealing on a female part of a 10/30 standard taper joint to accommodate a Sargent Thermometric Element (No. S-81630). A side arm with glass stoppered cap was provided for the introduction of the sample and Teflon covered stirring bar.

The change in resistance of the thermistor during cooling was followed by a Brown Electronik recorder using a modification of the bridge described by Ewing[5]. As the sample began to freeze, the leads of the thermistor were switched to a 5 dial Wheatstone bridge (Rubicon Instruments, Model 1041A) and galvanometer (Leeds & Northrup, Model 2430-A) wfhich permitted measuring the resistance to the nearest 0.1 ohm.

The equation which relates the resistance of a thermistor to temperature over short temperature ranges is:

$$\ln r_2/r_1 = B(1/T_2 - 1/T_1) \qquad \text{(Eq. 1)}$$

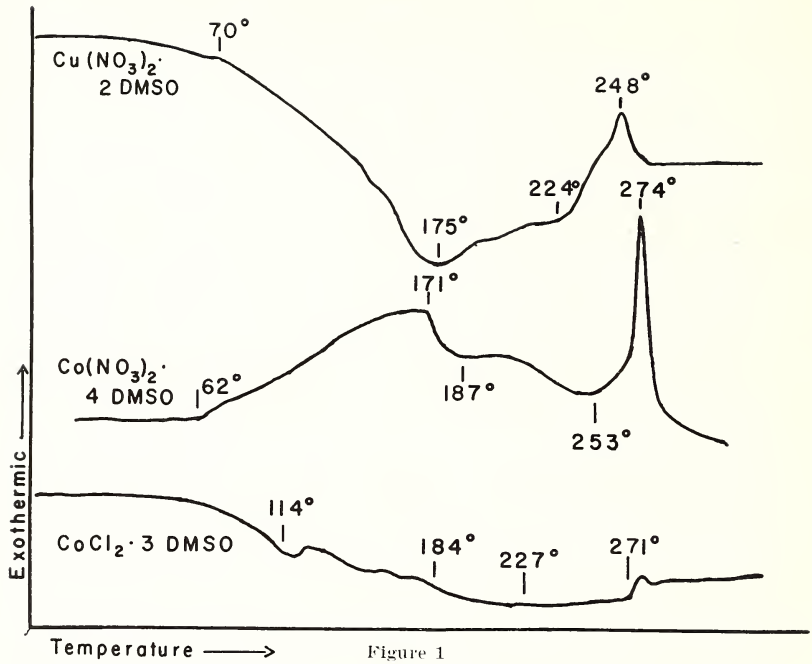


Figure 1

Figure 1. Differential Thermographs. Heating rates were approximately 5°C/minute.

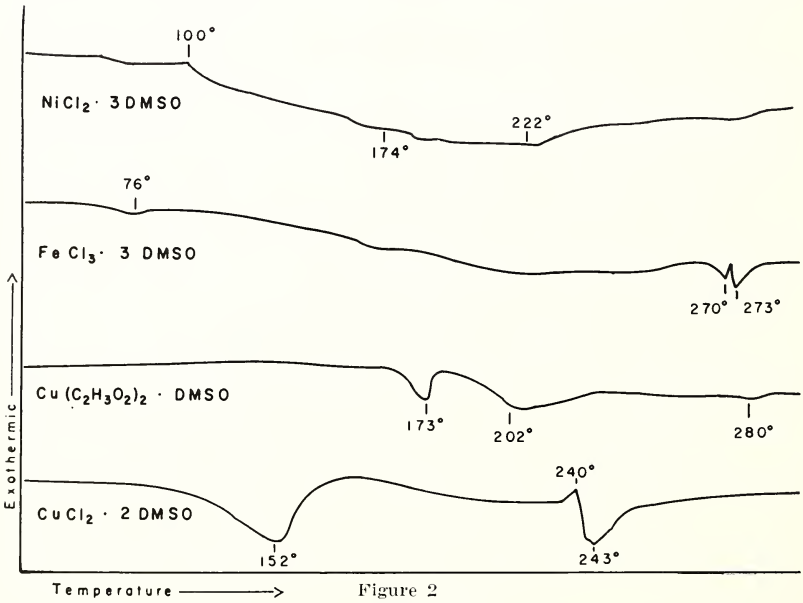


Figure 2

Figure 2. Differential Thermographs. Heating rates were approximately 10°C/minute.

The constant, B, for the thermistor was found to be 3380.2. Values of r and T for the freezing point of benzene (Mallinckrodt Analytical Reagent) and distilled water were substituted in Equation 1.

McMullan and Corbett[10] have shown that molal concentration, m, can be related to the measured resistance in the following manner:

$$m = K[\Delta r/r_o - 1/2(\Delta r/r_o)^2] \qquad \text{(Eq. 2)}$$

where Δr is the change in resistance on addition of the sample to the pure solvent.

Samples of urea and naphthalene (J. T. Baker, C. P. Grade) dissolved in DMSO were used to determine K = 6.154.

It was found that the resistance of the thermistor gradually increased during the ten-minute interval the cooling curve was followed with the Rubicon bridge. This corresponded to the lowering of the freezing point of the solution which was being concentrated by the freezing of the solvent. To obtain a value of r which was independent of cooling rate, a plot of time versus resistance was made. A timer was started at the first indication of freezing on the chart of the Brown recorder. Two sets of data on the same sample at different cooling rates gave almost identical values at time zero by extrapolation. This value was used in calculating Δr.

No attempt was made to correct for errors introduced by supercooling of the DMSO. Refinements of this type would be justified if a more accurate bridge for the measurement of resistance were to be used. Since DMSO and the complexes are hygroscopic, the samples were pressed into pellets and transferred into the freezing point vessel inside a desiccated glove box.

The $CaCl_2$ and $HgCl_2$ used were Mallinckrodt Reagent grade while KI was J. T. Baker Reagent grade.

5. Conductance Apparatus and Procedure—The conductance apparatus consisted of an Industrial Instruments Model RC-16B bridge and cell. The constant of the latter was 0.115 cm^{-1}.

The DMSO was refluxed over calcium oxide and distilled in a Todd fractionating column at a pressure of 5-10 mm Hg. The specific conductance of the middle fraction was 3.6×10^{-7} ohm^{-1} cm^{-1}.

The complexes were pressed into pellets, weighed and dissolved in DMSO without contact with moist air. It is of interest to note that the addition of a drop of water to the solutions did not appreciably change the conductance. The conductance measurements were made at 25± 1°C and at 60 cycles/second.

Results and Discussion

1. Differential Thermal Analysis—The reproductions in Figures 1 and 2 of the recorder tracings are not linear in temperature nor are the heating rates identical. While there will be some base line drift in all thermograms, the breaks correspond to exothermic or endothermic changes in the sample and are of interest.

The same samples were heated on a melting point block where they could be readily observed. The usual pattern of behavior for the complex on heating was melting, bubbling or boiling or liquid in the range 160-250°,

and reappearance of a solid phase. The more interesting observations will be correlated with the thermograms in the following abbreviated manner:

$NiCl_2 \cdot 3DMSO$—Blue green solid, m.pt. 100°, dark green liquid, bright orange solid at 225°.

$FeCl_3 \cdot 3DMSO$—Yellow solid, m.pt. 76°, yellow liquid; yellow solid changing to brown, 270-80°.

$Cu(OAc)_2 \cdot DMSO$—Blue green solid, orange then black solid, charring of acetate, 280°.

$CuCl_2 \cdot 2DSMO$—Chartreuse solid, began melting 110°, complete by 152°, brown liquid, white solid at 243°.

$Cu(NO_3)_2 \cdot 2DSMO$—This formula is given this complex on basis of work by Cotton and Francis[2]. Blue solid, m.pt. 65°, blue green liquid, black solid at 248°. This latter is an exothermic change probably corresponding to oxidation of DMSO by nitrate.

$Co(NO_3)_2 \cdot 4DMSO$—Magenta solid, m.pt. 62°, purple liquid, black solid at 274°, oxidation of DMSO by nitrate. Note sharpness of peak at 274°.

$CoCl_2 \cdot 3DMSO$—Deep blue solid, m.pt. 114°, dark blue liquid, pale blue solid by 275°.

With the exception of $CuCl_2 \cdot 2DMSO$ very little heat is absorbed in the melting process. Peaks such as the 274° peak for $Co(NO_3)_2 \cdot 4DMSO$ are much sharper at a heating rate of 10°/min. rather than 5°/min.[1]

2. Ions in Solution—The results of the conductance measurements are recorded in Table 2. The copper acetate complex only increased the conductivity of the DMSO from 1.1 x 10^{-6} to 1.8 x 10^{-6} ohm^{-1} cm^{-1} for a 2.24 x 10^{-3} molar solution and thus may be classed as a non-conductor.

The compounds with the exception of KI do not give a linear plot for Λ versus $\sqrt{C}$. In the case of KI the limiting equivalent conductance obtained from this plot is 38.5 compared with 38.2 ohm^{-1} $eq.^{-1}$ cm^2 reported by Sears et al[13].

The Shedlovsky equation[14] which follows was found useful:

$$\frac{\Lambda \div \beta \sqrt{C}}{1 - \alpha \sqrt{C}} = \Lambda_o' = \Lambda_o + BC \qquad \text{(Eq. 3)}$$

The values of the constants, $\alpha = 0.502$ and $\beta = 35.7$ were previously evaluated[13]. A plot of Λ_o' versus C was used for each complex to estimate Λ_o. The plots were extrapolated to zero concentration to obtain the values of Λ_o recorded in Table 3. These plots were not linear but sufficiently close that fair extrapolations could be made.

Other types of treatment of the data such as the Fuoss-Shedlovsky equations[6] were considered but the data is not sufficiently precise or complete to warrant such treatment. A good discussion of the problem involved is found in Chapter 17 of Hamer[7].

In the above treatment, a choice had to be made in regard to the equivalent weights of solid complexes. These equivalent weights are listed in Table 2 under the empirical formula as a fraction of that formula weight. The choice of this equivalent weight was based on the assumption that the limiting equivalent conductance calculated must be reasonably close to the values obtained for KI and $CaCl_2$. Also the equivalent weight

TABLE 3

Limiting Equivalent Conductances and Van't Hoff Factor for Complexes in Dimethyl Sulfoxide

Empirical Formula	Possible ions	Λ_o	$m_o \times 10^2$	i	Limiting Value
$Co(NO_3)_2 \cdot 4DMSO$	Co^{2+}, $2NO_3^-$	45.5	1.028	2.61	3
			2.304	2.42	
			5.193	2.29	
$CoCl_2 \cdot 3DMSO$	Co^{2+}, $2Cl^-$	42.5	1.303	1.19	3
$NiCl_2 \cdot 3DMSO$	Ni^{2+}, $2Cl^-$	41	1.618	2.18	3
$FeCl_3 - 3DMSO$	$FeCl^{2+}$, $2Cl^-$	31	1.921	1.65	3
$CuCl_2 \cdot 2DMSO$	$CuCl^+$, Cl^-	42.5	2.982	1.10	2
$Cu(OAc)_2 \cdot DMSO$	$[Cu(OAc)_2]_2$	...	1.181	1.11	1
KI	K^+ I^-	38.5	1.535	1.84	2
$CaCl_2$	Ca^{2+}, $2Cl^-$	45.7	3.061	1.92	3
$HgCl_2$	$HgCl_2$	...	14.65	1.05	1

chosen must be related to the number of ions suggested by the cryoscopic measurements.

The Van't Hoff factor, i, as used here, is defined as the ratio of molality, m, calculated by Equation 2 to the molality, m_o, obtained from the weights of solute and solvent. The factor, i, in infinitely dilute solutions, should approach a value equal to the number of ions per molecule. This limiting value of i, m_o, and the Van't Hoff factor, i, are tabulated in Table 3. There is only one simplest choice of formula weight, equivalent weight and number of ions which will satisfy both the conductance and cryoscopic data. For example, a formula weight corresponding to $Cu(OAc)_2 \cdot DMSO$ gave a value for i of 0.55. Since the complex is a non-conductor, it must be a dimer in solution. The number of DMSO molecules per metal atom in solution was not determined and therefore omitted in writing the "possible ions" in Table 3.

In the case of the cobalt chloride complex, if one uses $[Co(DMSO)_6]^{2+}$, $[CoCl_4]^{2-}$ as the basis for calculations, one calculates a value of about 70 for the equivalent conductance of the most dilute solution and a Van't Hoff factor of 2.38. The first value should be about 35 and the latter could not be larger than 2 for the above ions.

The equivalent conductance calculated on the basis of $CoCl^+$, Cl^- would also be 70 and equally unsatisfactory. However the Van't Hoff factor would be 1.19 which would be satisfactory for 2 ions.

Complete dissociation into Co^{2+}, $2Cl^-$ gives the values in Table 3. The value for i seems unreasonably low for 3 ions. Daniels and Alberty[3] give values of i in graphical form for aqueous solutions but none deviate so widely from the limiting value.

A plot of $\Lambda - \Lambda_o$ versus $\sqrt{C}$ comparing the complexes with KI and $CaCl_2$ shows the complexes of $NiCl_2$, $Co(NO_3)_2$ and $FeCl_3$ approaching the curve for $CaCl_2$, a 2:1 salt. The data for $CuCl_2 \cdot 2DMSO$ does not approach the curve for KI as it should if it is a 1:1 salt[6].

It is widely accepted[9] that the blue color of Co^{2+} complexes indicates a coordination number of 4 while a pink or magenta color indicates a coordination number of 6. This is the basis for Cotton and Francis'[2] assignment of the structure: $[Co(DMSO)_6]^{2+}$, $[CoCl_4]^{2-}$. The blue color of $[CoCl_4]^{2-}$ is more intense than the pink color of the cation and the solid has a deep blue color. The dilute solutions used in this research still had this blue color and thus suggest the presence of the $[CoCl_4]^{2-}$ ion even in these solutions. This may indicate the presence of several ionic species in equilibrium.

Complexes, ion pair formation and ion association as discussed in Chapter 25 of Hamer[7] may need to be considered in a complete explanation of the conductance and cryoscopic behavior.

McMullan and Corbett[10] have shown that K in Equation 2 is related to the heat of fusion in the following manner:

$$K = \frac{1000\ \Delta H}{RBM} \qquad \text{(Eq. 4)}$$

When the value for B calculated from Equation 1 and known values for the gas constant and molecular weight are taken, the heat of fusion, ΔH, calculated from Equation 4 is 41.3 calories/gram. This throws some doubt on the value of 20 calories/gram currently reported by a manufacturer of DMSO in their technical literature.

The molal freezing point constant calculated for DMSO is 4.09 degree/mole.

Conclusion

In respect to the stated objectives, differential thermal analysis was unsuccessful in detecting the stepwise loss of DMSO from the complexes because the complexes melted too low, and DMSO was not sufficiently volatile. However characteristic curves were obtained and exothermic breaks for nitrate containing complexes probably corresponding to the oxidation of DMSO by nitrate were found.

The cryoscopic and conductance measurements show that the structures suggested by Cotton and Francis for the solids do not exist in solution. The complex derived from copper acetate is a non-electrolyte in solution and is a dimer, $Cu_2(OAc)_4$ x DMSO.

The complexes derived from cobalt nitrate and nickel chloride seem to dissociate completely in dilute solution while those derived from cobalt chloride, ferric chloride and copper chloride show more complicated equilibria.

This preliminary work indicates that future work involving more precise measurements at dilute concentrations coupled with spectrophotometric measurements should indicate the nature of the ions in solution.

Literature Cited

1. BORCHARDT, H. J. 1956. Differential thermal analysis. J. Chem. Ed. 33 : 103-7.
2. COTTON, F. A. and R. FRANCIS. 1960. Sulfoxides as ligands. I. A. preliminary survey of methyl sulfoxide complexes. J. Am. Chem. Soc. 62 : 2986-91.
3. DANIELS, F. and R. A. ALBERTY. 1955. Physical chemistry. John Wiley and Sons, Inc., New York. p. 231.
4. DOUGLAS, T. B. 1946. Heats of formation of liquid sulfoxide and crystalline methyl sulfone at 18°. J. Am. Chem. Soc. 68 : 1072-76.

5. EWING, G. W. 1956. The recording potentiometer, its use in the Analytical Chemistry laboratory. J. Chem. Ed. 33 : 424-30.

6. FUOSS, R. M. and T. SHEDLOVSKY. 1949. Extrapolation of conductance data for weak electrolytes. J. Am. Chem. Soc. 71 : 1496-98.

7. HAMER, W. J., Editor. 1959. The structure of electrolytic solutions. John Wiley and Sons, Inc., New York.

8. HARNED, H. S. and B. B. OWEN. 1958. The Physical chemistry of electrolytic solutions. Reinhold Publishing Corp., New York. p. 198-213.

9. KATZIN, L. I. 1957. Factors affecting the solution of inorganic salts in organic solvents. J. Inorg. anl Nuclear Chem. 4 : 187-204.

10. MCMULLAN, R. K. and J. D. CORBETT. 1956. The use or thermistors in cryoscopic measurements. J. Chem. Ed. 33 : 313-17.

11. PAKULAK, J. M., JR. and G. W. LEONARD. 1959. Thermistorized apparatus for differential thermal analysis. Anal. Chem. 31 : 1037-39.

12. SAETTLER, E. 1957. Solvates of dimethyl sulfoxide. Abstracts of papers, First annual symposium in miniature, Purdue section of the Am. Chem. Soc. p. 1.

13. SEARS, P. G., G. R. LESTER and L. R. DAWSON. 1956. A study of the conductance behavior of some uni-univalent electrolytes in dimethyl sulfoxide at 25°. J. Phys. Chem. 60 : 1433-36.

14. SHEDLOVSKY, T. 1932. An equation for electrolytic conductance. J. Am. Chem. Soc. 54 : 1405-11.

15. SPIELMAN, M. 1951. A simple method for butt welding fine wires. Rev. Sci. Inst. 22 : 216.

16. ———— Technical information on dimethyl sulfoxide. Crown Zellerbach Corp.

Some One Dimensional Atomic Potential Functions

JOHN A. RICKETTS and LARRY D. NICHOLS, DePauw University

The problem of finding a one dimensional potential field which gives a one dimensional wave function exactly analogous to that found through the solution of the appropriate three dimensional Schrodinger equation might offer a useful approach to chemical bonding approximations. In the following treatment such functions will be developed for any s or p state of a hydrogen-like atom or ion.

The ground state wave function for the hydrogen atom is

$$\Psi = \exp\ (-r) \qquad (1)$$

where r represents the radial distance from the nucleus as measured in atomic units (1). The normalizing constant has been omitted from eq. 1 since its inclusion is unnecessary for the present discussion. The one dimensional analogue of eq. 1 is

$$\Psi = \exp\ (-|x|)\,. \qquad (2)$$

Equation 2 must satisfy the one dimensional Schrodinger equation which when expressed in atomic units is

$$-\tfrac{1}{2}\frac{d^2\Psi}{dx^2} + V\Psi = E \qquad (3)$$

for some potential function V. The potential function may be written as the sum of two contributions, $V = V_o + V_x$. V_o is its form at the nucleus, $x = 0$, and V_x is its form for $x + 0$. In addition the potential function must be such that as $|x| \to \infty$, $V \to 0$, and must not be zero everywhere.

The dimensionless electronic energy associated with 1s state for the hydrogen atom is $E = -\tfrac{1}{2}$; therefore, the potential function must vanish at all points other than at the nucleus. To determine its nature at the nucleus multiply eq. 3 by dx and integrate the expression,

$$-\tfrac{1}{2}\int_{-\epsilon}^{+\epsilon}\frac{d^2\Psi}{dx^2}\,dx + \int_{-\epsilon}^{+\epsilon} V\Psi\,dx = \int_{-\epsilon}^{+\epsilon} E\Psi\,dx \qquad (4)$$

between the limits $-\epsilon$ and $+\epsilon$ where ϵ is an infinitesimal interval of length on either side of the nucleus. Let ϵ approach zero. Since Ψ is well-behaved, it is finite at the nucleus; therefore, $\lim_{\epsilon \to 0}\int_{-\epsilon}^{+\epsilon}\Psi\,dx$ vanishes. The quantity, $\int_{-\epsilon}^{+\epsilon}\frac{d^2\Psi}{dx^2}\,dx$, becomes $\Delta\left[\frac{d\Psi}{dx}\right]_{x=o}$, the change in the slope of the wave function in passing through the origin in a positive direction. For the wave function, $\exp\ (-|x|)$, $\Delta\left[\frac{d\Psi}{dx}\right]_{x=o} = -2$. Consequently, it is necessary that

$$\lim_{\epsilon \to 0} \int_{-\epsilon}^{+\epsilon} V \Psi \, dx = \Psi (0) \lim_{\epsilon \to 0} \int_{-\epsilon}^{+\epsilon} V \, dx = -1 \qquad (5)$$

The conditions that a function, $f(x)$, be zero for $x + 0$ and that $\int_{-\infty}^{+\infty} f(x) \, dx = -1$ defines a negative Dirac delta function (2) of unit strength placed at the origin. For the one dimensional 1s state for the hydrogen atom, $V = -\delta(x)$. Table 1 summarizes those potential functions that yield the correct one dimensional 1s, 2s, 2p, 3s, and 3p wave functions for the hydrogen atom. It is interesting to note that each of these potentials may be described as the sum of a set of rectangular hyperbolas, each member of which has its vertical asymptote at a node of the corresponding wave function.

TABLE 1

One Dimensional Potential Functions for the Hydrogen Atom

Energy States	Wave Function	Potential Function
1s	$\exp\left(-\lvert x\rvert\right)$	$-\delta(x)$
2s	$(2 - \lvert x\rvert) \exp\left(-\frac{\lvert x\rvert}{2}\right)$	$\frac{1}{2(2 - \lvert x\rvert)} - \delta(x)$
2p	$x \exp\left(-\frac{\lvert x\rvert}{2}\right)$	$-\frac{1}{2\lvert x\rvert}$
3s	$(27 - 18\lvert x\rvert + 2\lvert x\rvert^2) \exp\left(-\frac{\lvert x\rvert}{3}\right)$	$\frac{4(6 - \lvert x\rvert)}{81 - 54\lvert x\rvert + 6x^2} - \delta(x)$
3p	$(6 - \lvert x\rvert) x \exp\left(-\frac{\lvert x\rvert}{3}\right)$	$\frac{2\lvert x\rvert - 7}{18\lvert x\rvert - 3x^2}$

Frost (3), (4), (5) has employed the Dirac delta function model to treat one electron atoms, diatomic molecules, and aromatic systems. The advantage of his model is that the linear combination of atomic orbitals is an exact solution of the Schrodinger equation. With this model correct united atom and separated atom electronic energies are realized for H_2^+; in the case of aromatic nuclei it predicts excitation energies, resonance energies, and ionization potentials for the pi electrons. The disadvantage of the model is inherent in the fact that inter-electronic interactions are not treated, and in the case of diatomic molecules the nuclear repulsion term must be modified in order to obtain the desired minimum in the potential energy curve. It should be stated here that Frost (6) conceived the delta function model through coulombic considerations and not in the manner presented in this paper.

In this next section the general problem of an electron moving in a field that is described by three delta functions will be discussed. The potential function is of the form

$$V = g\,\delta\,(x + \frac{R}{2}) + g_o\,\delta\,(x) + g\,\delta\,(x - \frac{R}{2}) \qquad (6)$$

where g and g_o are the delta function strengths which may be positive or negative and $\frac{R}{2}$ in atomic units represents the displacement of the delta function from the origin. The appropriate wave function can be represented as a linear combination of atomic orbitals having the form

$$\Psi = A \exp(-c\,|x + \frac{R}{2}|) + B \exp(-c\,|x|) + C \exp(-c\,|x - \frac{R}{2}|) \qquad (7)$$

except at the points, $+\frac{R}{2}$ and zero. The energy is given as $E = -\frac{c^2}{2}$.

In order to solve the wave equation is is necessary to apply the delta function condition at each delta function. This condition is outlined below for the point $+\frac{R}{2}$.

$$-\tfrac{1}{2}\int_{R/2-}^{R/2+} \frac{d^2\Psi}{dx^2}\,dx + \int_{R/2-}^{R/2+} g\,\delta\,(x - \frac{R}{2})\,\Psi\,dx = \int_{R/2-}^{R/2+} E\,\Psi\,dx \qquad (8)$$

$$-\tfrac{1}{2}\,\Delta\left[\frac{d\Psi}{dx}\right]_{R/2} + g\,\Psi\,(\frac{R}{2}) = 0 \qquad (9)$$

Application of the above condition at each of the three points leads to the following secular equation for a non-trivial solution,

$$\begin{vmatrix} g + c & g \exp(-\frac{cR}{2}) & g \exp(-cR) \\ g_o \exp(-\frac{cR}{2}) & g_o + c & g_o \exp(-\frac{cR}{2}) \\ g \exp(-cR) & g \exp(-\frac{cR}{2}) & g + c \end{vmatrix} = 0 \qquad (10)$$

Equation 10 reduces to the equality that

$$\exp(-cR) = \frac{(g + c)\,(g + c)}{g\,(g_o - c)} \qquad (11)$$

with the values for the normalizing constants expressed in terms of A given as

$$C = A$$

$$B = -A\left[(1 + \frac{c}{g})\exp(+\frac{cR}{2}) + \exp(-\frac{cR}{2})\right] \qquad (12)$$

If the negative sign in eq. 11 is adopted, the solution reduces to the nodal (higher energy) solution of the symmetrical two delta function model discussed by Frost (reference 4). When the positive sign is assumed, non-nodal possibilities result, the forms of which depend upon the relative

magnitudes of the delta function strengths, g and g_o, and the value of the parameter c. The permitted values of g,g_o, and c can be determined through the analysis of the inequality,

$$0 < \frac{(g + c)\ (g_o + c)}{g\ (g_o - c)} < 1$$

The results of this analysis are summarized in Figure 1 which was constructed using the fact that for a non-nodal solution the ratio

$$\frac{\Psi\ (0)}{\Psi\ (R)} = -\ \frac{2\ g}{g_o + c} \left[\frac{(g + c)\ (g_o + c)}{g\ (g_o - c)} \right]^{1/2} \qquad (14)$$

must be greater than zero; therefore $\frac{g}{g_o + c}$ must be negative. In the figure the delta function strength g_o is plotted as abscissa in units of the parameter c while the delta function strength g is plotted as ordinate in the same units. Within the allowed areas are sketched the forms of the wave functions.

Literature Cited

1. W. KAUZMANN, "Quantum Chemistry," Academic Press Inc., New York, (1957), p. 176.
2. L. I. SCHIFF, "Quantum Mechanics," McGraw-Hill Book Company Inc., New York, (1949), p. 50.
3. A. A. FROST. J. Chem. Phys., **22**, 1613 (1954).
4. A. A. FROST. J. Chem. Phys., **25**, 1150 (1956).
5. A. A. FROST and F. E. LELAND, J. Chem. Phys., **25**, 1154 (1956).
6. A. A. FROST, private communication.

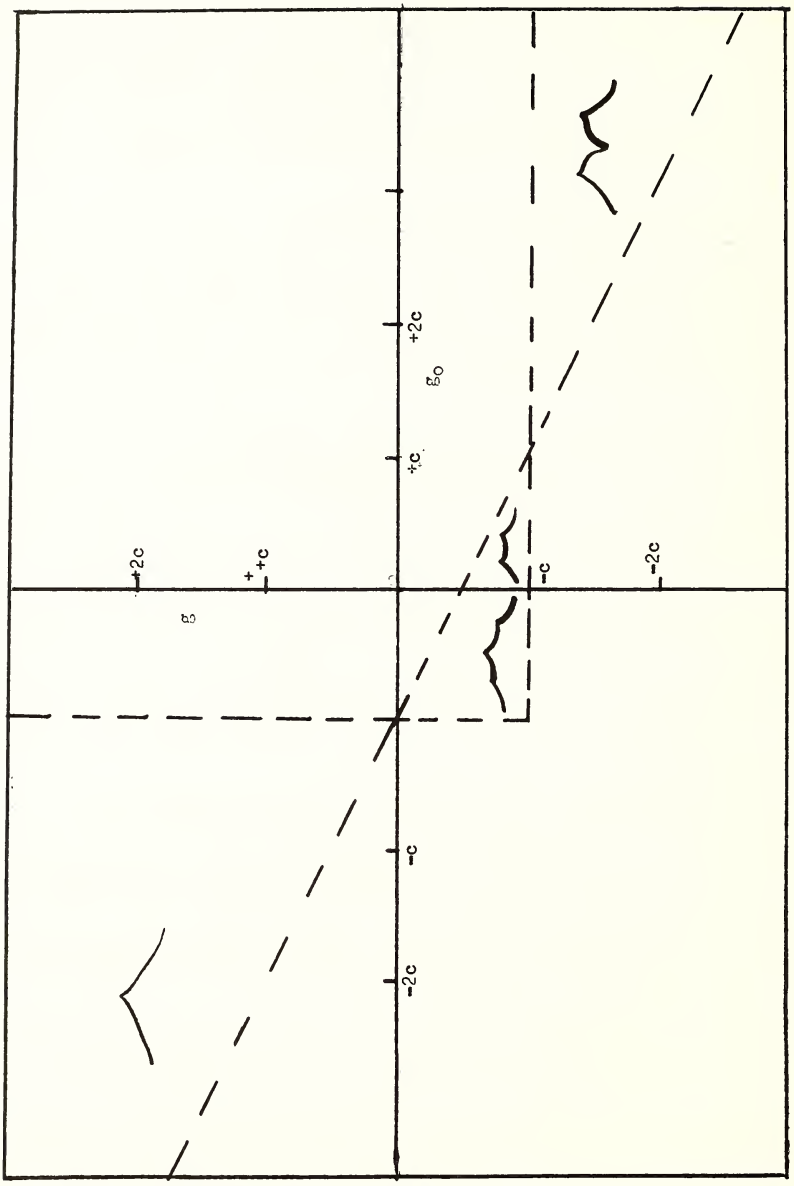


Figure 1. Regions of Existence of Non-nodal Wave Functions for the Three Delta Function Model.

ENTOMOLOGY

Chairman: R. E. Niswander, Manchester College
R. E. Siverly, Ball State Teachers College, was elected chairman for 1961

ABSTRACTS

Sorghum Resistance to the Corn Leaf Aphid, *Rhopalosiphum maidis* (Fitch). Benjamin T. Ford, Pennsville, N. J., and Ray T. Everly, Purdue University.—The corn leaf aphid is a common pest of sorghum and corn and when abundant can result in serious loss of yield. Due to its habit of infesting the whorl, leaf sheaths and other inaccessible areas, resistance in the host plants to attack and survival of the aphid would provide an ideal method of control. In this study, 23 sorghum varieties and one corn hybrid were infested in the seedling stages under greenhouse conditions with mature apterous corn leaf aphids. Highly statistically significant differences between the sorghum varieties were found in the number of aphids developing on the plants 2 weeks following infestation.

The Use of Light Traps to Protect Tobacco in Southern Indiana from Tobacco and Tomato Hornworms. H. O. Deay, Purdue University, and J. G. Hartsock, A.R.S., U. S. Department of Agriculture.—Experiments were conducted in Jefferson County, Indiana, from 1954 to 1959 on the control of tobacco and tomato hornworms [*Protoparce sexta* (Johan.) and *P. quinquemaculata* (Haw.)] on tobacco. On an average, one trap equipped with one 15-watt BL lamp decreased the number of plants infested 73.5 per cent and the amount of leaves eaten 77.4 per cent in an area 100 feet from the trap.

Occurrence of *Aedes thibaulti* Dyar and Knab in Indiana. R. E. Siverly, Ball State Teachers College.—Larvae of *Aedes thibaulti* D. and K. were collected during the spring of 1960 in a bog area in Delaware County, Indiana. This mosquito is generally regarded as southeastern U. S. in distribution, but has been reported from Illinois. Breeding sites are usually restricted to tree cavities at ground level. Locally, it was taken at such a site, in breeding association with *Aedes aurifer*. To the author's knowledge, there are no previous records of the occurrence of *A. thibaulti* in Indiana. Identification is confirmed in the adult stage by the peculiarly modified claspette filament of the male terminalia.

New Materials for the Control of Cabbage Worms. George E. Gould, Purdue University.—Two insects, the imported cabbage worm [*Pieris rapae* (L.)] and the cabbage looper [*Trichoplusia ni* (Hbn.)], continue to be a major problem in the production of cabbage and related crops. When DDT first became available in 1945, this new insecticide gave spectacular control of both caterpillars. Then in the mid-1950's, commercial growers in Marion and Lake counties reported poor results with this material. In our experimental tests, DDT continued to be the outstanding insecticide until 1958 when it dropped in efficiency below that of several other materials. In 1960, the rate per acre for DDT was doubled and again it was one of the better materials. Other insecticides found to be effective

against the two caterpillars included endrin, toxaphene and parathion. The new phosphate insecticides, in general, gave an excellent quick kill, but plants were reinfested in a week. A new biological control agent made up of live spores of *Bacillus thuringiensis* has been tested extensively against the two caterpillars on cabbage and against the mint looper on peppermint and spearmint. In all tests, the material gave fair to good initial kills, but plants were reinfested in about seven days.

Differential Predation in *Osmia cordata* Robt.—*O. lignaria* Say Nesting Associations (Hymenoptera, Megachilidae). LELAND CHANDLER, Purdue University.—Females of *Osmia cordata* and of *O. lignaria* constructed nests in sections of hollow elderberry stems that had been placed as trap nests. Various combinations of stem occupancy by the two species were obtained. Predation by the larvae of several species of Dermestidae was responsible for the destruction of 91.7 per cent of the cells of *O. cordata* in stems which had been occupied solely by that species. In stems containing cells of both species, only 42.1 per cent of the *O. cordata* cells were destroyed. The cells of *O. lignaria* were destroyed only when dermestid infestation occurred prior to cell closure. A major factor contributing to the observed differential predation upon the two species is the different materials utilized in cell construction. *O. lignaria* constructs cells of mud; *O. cordata* uses chewed plant materials.

An Inherited Color Factor in the German Roach, *Blattella Germanica* (L). R. E. NISWANDER, Manchester College.—The usual color pattern of the German roach is black with light brown or cream markings. The color variation observed concerns the change of the black to a light brown or red color. This difference in color is easily observed in nymphs before wings develop. But the color differences can be seen in the adults with closer observation. A pure strain of both color types was developed by isolating females with egg capsules and observing the offspring as to color. By isolating these offspring, allowing them to mature, crosses were made which showed the black color was dominant with the red color being recessive. The results show this to be a simple dominant and recessive factor with no evidence of sex linkage.

Quantitative Comparison of Insect Orders from Three Types of Vegetational Cover on Miami, Bethel and Brookston Soils in Eastern Indiana

GERTRUDE L. WARD and CAROL COLE, Earlham College[1]

For a three-week period during the summer of 1960, a study was made of the insects occurring in the vegetation on three types of soil with different drainage conditions in Wayne County, Indiana. The three soil types chosen, Miami, Bethel and Brookston, are some of the most extensive soils of the county. Miami silt loam occupies the smoother slopes of stream valleys. It is an arable soil derived from glacial tills and has a fine granular structure. Surface drainage is good. The Bethel silt loam occurs on the flattest parts of main divides remote from any stream. This soil is also of glacial till origin. The surface drainage is rather poor. The Brookston silty clay loam is found on smooth, flat, low areas. The surface drainage is very poor with water sometimes standing for months after a rain unless it is drained artificially.

Nine collecting sites were chosen, three sites from each type of soil, with a different type of vegetational cover at each of the three sites. The three vegetational covers chosen were woodland, cropland and pasture. Vegetation in woods and pasture directly reflected soil type while cropland reflected it only in amount of growth. All sites are located near the Centerville-Williamsburg Road, Wayne County. The three wooded sites are located in Lewis Woods, an 80 acre classified woods that has been used by Earlham College for several years as a study area. On the Miami site the principal tree is sugar maple. There are also some sycamores and beech. The floor covering is not dense. It consists primarily of woodbine, May-apple, false Solomon's seal and maple seedlings. On the Bethel site the trees are beech and maple with maple predominating. The principal floor covering is nettle, with jewelwood, May-apple and false Solomon's seal. The Brookston site also has beech and maple with maple predominating, but the beech are not as plentiful as on the Bethel site. Some ash and elm were also found on this site. The floor covering is again primarily nettle with jewelweed and maple seedlings, but the vegetation is more dense than on the Bethel site.

The cropland sites were sowed to corn in 1960. The Miami and Brookston sites are located in the same field while the Bethel site is two miles to the south.

The pasture sites are all grazed pastures. The Miami site's cover is chiefly grasses with some chicory and clover. Vegetation of the Bethel pasture is mainly clover with some fleabane and yarrow. The Brookston pasture is not heavily grazed and vegetation is high. It includes mainly grasses, plus fleabane, curly dock, sedges, boneset, clover, alfalfa, daisies and Queen Anne's lace. A stream runs through this pasture and the area is damp.

---

1. The authors wish to acknowledge the guidance of James Thorp and Ansel M. Gooding in selection of soil plots, and the financial support of the Charles F. Kettering Foundation and NSF Research Participation program.

Method

Three collecting trips were made, one week apart, to each of the nine sites, all sites being visited on the same day. The first trip was on July 12, 1960. Collecting was done by sweeping with a 15" diameter net. The junior author made 60 sweeps at each site, emptying the net into the killing jar after 10 sweeps. The insects were then taken to the laboratory and sorted from vegetational debris before being weighed. There appeared to be some water loss, and hence weight loss, by this method, but the ranking of orders proved to coincide with that of later trips so possibly the weight was lost evenly.

Trip two was taken on July 20. To cut down on water loss the insects from only four sites were placed in killing bottles. These four collections were weighed the same day. The other insects were placed in jars and kept alive until the following day when they were killed and weighed.

The third trip was taken on July 27. There had been rain the previous day, and the woods areas were still very damp. This appeared to cut down the number of insects collected. The same method of collection was used as on trip two.

Results

Totals from the three collecting days are shown on Table 1. A comparison can also be made with the top four orders, for example, ranking

Table 1. Total Numbers of Insects from Nine Collecting Sites, and Percentages According to Weight

Orders:	Odon.	Orth.	Hemi.	Homo.	Neur.	Cole.	Meco.	Lepi.	Dipt.	Hyme.
Sites										
Miami:										
Wood	0	1	2	115	1	28	1	2	79	16
		0.2%	0.5%	61.7%	0.5%	9.1%	1.1%	0.5%	18.3%	8.1%
Crop	0	14	62	32	1	64	0	0	56	5
		24.2%	7.2%	12.7%	0.9%	44.6%			6.8%	3.6%
Past.	0	16	27	111	0	44	0	0	451	46
		34.8%	10.6%	23.2%		13.9%			9.0%	7.7%
Bethel:										
Wood	0	1	1	64	1	36	4	11	95	13
		14.7%	0.5%	35.2%	3.0%	12.9%	3.9%	4.9%	17.6%	6.9%
Crop	0	0	7	19	0	68	0	0	19	0
			5.6%	30.0%		47.2%			17.2%	
Past.	0	14	124	497	0	36	0	5	181	21
		9.9%	5.7%	70.2%		1.6%		0.2%	7.1%	5.3%
Brooks.:										
Wood	0	2	1	37	0	36	5	21	98	15
		17.7%	1.0%	28.6%		14.3%	3.1%	7.8%	24.9%	2.6%
Crop	0	22	69	42	1	100	0	1	52	7
		16.7%	15.7%	14.0%	0.7%	44.0%		0.8%	6.7%	1.4%
Past.	3	39	99	337	0	43	0	1	156	4
	0.5%	46.1%	6.0%	37.0%		2.5%		0.2%	6.1%	1.6%

them with most numerous, and heaviest, at the top of their respective lists. It is these four groups which probably have the greatest effect on amount of vegetation eaten and amount of fecal matter and other organic matter contributed to the soil.

Summary

As a result of the study of nine collecting sites located on Miami, Bethel and Brookston soils in eastern Indiana, it can be seen that the soil types have an indirect effect on the insects by influencing the density of the vegetaation.

Judging by weight, Homoptera is the top ranking insect order in all woods collections. Coleoptera ranks heaviest in all cropland collections, and Orthoptera ranks first in two pastureland total collections, with Homoptera highest in the third.

Diptera Populations in the Whitewater Valley

GERTRUDE L. WARD and TERRENCE G. MARSH, Earlham College[1]

As part of an insect survey conducted under the Earlham College soil research program, we are attempting to discover whether or not relationships exist between insects and soil types of the Whitewater Valley. This report is the result of collections made from June 6 to August 12, 1960, on the Genessee silt loam of streams of the northern half of the Whitewater drainage basin.

Field collections from 14 localities yielded 1,835 pinned Diptera, the insect order with which this report is concerned. Collecting was by sweeping with 15" diameter nets and collecting some individual insects by hand. Collecting was limited to within approximately 50 feet of the stream, on each bank, and sweepings were made in all vegetational habitats within this area. Identifications were made with a Spencer binocular microscope with powers ranging from 7x to 80x. Borror and DeLong (1) was used for family identifications and Curran (2) was used for classification to genus of some specimens.

Survey Sites

All of the survey sites were in pastures and woods of different types. For example, some of the pastures were inhabited by cows, horses, sheep or hogs; some were abandoned; others were combinations of woods and pasture. There was very little cropland close to the streams. The natural environment along these streams is woodland. Here the soil holds a great quantity of water, and decaying vegetation is abundant. Tree holes and intermittent streams provide moist spots where many Diptera breed. An example of the effect of these moisture factors can be seen in the abundance of moisture-loving plants such as poison hemlock and jewelweed. Because of the additional moisture which the stream gives to this woodland, we have termed this the "moist woods-stream" habitat.

Results

The moist woods-stream habitat is particularly favorable to a great quantity and variety of Diptera. Table 1 shows the numbers of each family of Diptera collected at each locality.

A similar table drawn up for the previous summer's collecting shows similar results. In 1959, at 12 collecting sites in the upper Whitewater Valley, the same 36 families of Diptera were collected plus an additional four families: namely, Dixidae, Rhyphidae, Mydaidae, and Lonchopteridae. The first three families were represented by one specimen respectively. There were 12 specimens collected of the last family. Families such as Dolichopodidae and Ephydridae were collected in abundance both summers, while Mycetophilidae and Therevidae were not taken in quantity either season.

In studying a narrow strip of stream bank, the fluctuation of the dipteran and other insect populations between habitats must be recognized.

---

1. The authors wish to acknowledge the assistance of Ansel M. Gooding in soil identification, and the financial support of the Charles F. Kettering Foundation and NSF Undergraduate Research Participation Program.

TABLE 1

Number of Dipteran Families Collected at Whitewater Valley Localities

	Webster	Fountain City	Centerville	Williamsburg	Green Township	Dalton	Centerville S. W.	Greensfork	East Germantown	Beeson	Richmond S. E.	Economy S.	Modoc	Jacksonburg
Tipulidae	12	6	16	30	18	7	11	2	5	20	6	5	12	5
Chironomidae	11	12	1	2	—	9	2	—	3	1	—	—	4	2
Ceratopogonidae	—	2	3	—	—	5	1	4	9	3	1	4	6	2
Culicidae	1	—	—	1	1	—	—	—	13	1	2	2	8	2
Mycetophilidae	—	1	—	—	—	—	—	1	1	—	—	—	—	1
Sciaridae	—	1	2	1	1	2	1	—	—	—	—	—	—	1
Stratiomyidae	2	2	1	1	—	1	8	3	4	1	4	3	3	1
Rhagionidae	6	5	7	4	18	6	8	—	5	3	4	4	10	1
Tabanidae	1	2	3	3	—	7	7	—	5	3	—	—	7	7
Therevidae	—	—	—	—	—	—	1	—	—	1	—	—	—	—
Bombyliidae	—	—	—	—	—	—	—	—	—	1	—	4	—	—
Asilidae	—	2	2	—	—	—	3	1	—	4	—	—	8	7
Empididae	4	7	1	1	9	7	3	—	6	1	7	2	11	1
Dolichopodidae	11	9	17	8	12	21	19	7	10	13	23	17	20	17
Phoridae	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Pipunculidae	2	—	—	—	—	—	7	—	—	—	—	—	1	—
Syrphidae	6	12	28	12	2	28	12	15	9	8	14	17	10	17
Conopidae	3	—	4	2	1	—	—	—	—	5	—	2	—	2
Otitidae	7	3	2	1	—	4	7	—	1	3	3	2	1	5
Trypetidae	4	3	2	—	1	2	3	1	—	4	4	4	1	1
Lauxaniidae	4	5	7	11	2	13	5	15	6	8	4	8	15	6
Sepsidae	9	4	12	7	—	6	3	22	2	6	10	11	11	1
Sciomyzidae	—	5	1	1	—	8	—	5	—	1	13	5	7	6
Heleomyzidae	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Psilidae	2	—	—	3	—	—	2	—	—	—	—	—	—	—
Agromyzidae	1	—	—	—	—	1	—	—	—	2	1	—	—	—
Drosophilidae	—	—	3	—	—	—	—	—	—	—	—	—	1	—
Ephydridae	6	12	17	12	5	27	8	10	11	12	13	4	11	2
Chloropidae	—	6	6	—	1	10	3	12	6	2	6	7	10	4
Sphaeroceridae	—	1	2	1	—	4	1	2	2	6	2	1	1	—
Tachinidae	1	—	2	5	1	1	2	2	1	1	5	4	3	4
Calliphoridae	—	1	2	5	1	2	—	1	—	—	3	3	—	3
Sarcophagidae	—	3	3	4	1	3	10	—	3	1	7	5	2	24
Muscidae	2	5	2	1	—	9	4	7	—	1	2	3	5	1
Anthomyiidae	2	4	15	2	1	7	3	12	1	1	4	3	14	7
Scopeumatidae	—	—	1	—	—	—	—	1	—	—	—	—	1	—

This is seen in the case of the Therevidae, which generally prefer an open area, but come to decaying vegetation to lay eggs. The Conopidae and

Pipunculidae may be accidentally present in the moist woods-stream habitat; because of the parasitic habit of their larvae, they would be found where their hosts were.

Further collecting might fill in many of the blanks in Table 1. The figures are significant in that they show that a family was present at a certain locality, and in relative scarcity or abundance.

Summary

Field collections at 14 localities along streams of the Whitewater Valley showed the presence of 36 families of Diptera. Families present at all localities were Tipulidae, Dolichopodidae, Syrphidae, Lauxaniidae, Ephydridae, and Anthomyiidae. Present in all but one locality were Stratiomyidae, Rhagionidae, Empididae, Sepsidae, and Tachinidae.

Literature Cited

1. BORROR, D. J. and D. M. DELONG. 1955. An Introduction to the Study of Insects. Rinehart and Co., N. Y.
2. CURRAN, C. H. 1934. The families and genera of North American Diptera. N. Y.: published by the author.

Insects and Other Arthropods of Economic Importance in Indiana in 1960[1]

JOHN V. OSMUN,[2] Purdue University

Among the principal factors governing the extent of insect population development each year are the weather conditions. Weather influences not only the insect but also its hosts. These conditions in Indiana in 1960 during the insect-development period can be characterized as "consistent" but with a few fluctuations. The latter included long periods of inundation in local southern areas and several dry periods in north central Indiana and southwest Indiana. April was relatively warm but the rest of the development season until mid-August experienced temperatures which were normal or slightly below normal. This condition had the effect of supporting insect development but retarding the rate in many species. With respect to moisture, conditions were especially favorable for many insects in that a modest but continuous supply of rain fell intermittently from April until the dry period late in September. Such conditions favored insects requiring moisture and those which develop large populations in lush vegetative growth.

Field and Crop Insects

Corn earworm [*Heliothis zea* (Boddie)]. Although moth flights were not as heavy in 1960 as in the previous year, larval infestations in sweet corn were heavy. Some plantings of both early and late corn were 100% infested. Because of spotty occurrences in southern Indiana, the total damage will be about equal to that of last year with fall damage being especially heavy.

European corn borer [*Pyrausta nubilalis* (Hbn.)]. Both the June and and August generations of moths were more abundant than in 1959. Late sweet corn had 60% of their stalks infested in central Indiana. In general infestations and populations were slightly higher than in 1959. This is particularly true in northern Indiana, and in the pocket counties of the southwest corner of the state. One field of white corn in Posey County north of Wadesville averaged more than two borers per plant with about 96% infestation.

Armyworm [*Pseudaletia unipuncta* (Haw.)]. Infestations below normal.

Fall armyworm [*Laphygma frugiperda* (J. E. Smith)] was of little economic importance in Indiana in 1960, probably due to rank growth of plants. Infestations in late-planted field corn were reported in localized areas of several south central counties.

Common stalk borer [*Papaipema nebris* (Guen.)] was more prevalent than the preceding year. Larvae damaged early-planted corn and were also found in wheat stems. Infestations were more common along weedy fence rows.

---

1. Purdue University Agricultural Experiment Station Journal No. 1681.

2. Information for this summary has been provided by: W. L. Butts, H. O. Deay, R. C. Dobson, R. T. Everly, R. L. Giese, G. E. Gould, D. L. Hamilton, D. L. Matthew, J. D. Paschke, D. L. Schuder, M. C. Wilson.

Cutworms—Several species were common during spring months. They caused significant losses to corn, mint and home gardens. The black cutworm, *Agrotis ypsilon* (Rott.), as in 1959, was the dominant species in corn fields.

Webworms [*Nomophila noctuella* (D. and S.)]. Not important in 1960.

Wireworms—Although activity by this complex group is indicated by the increased use of soil insecticides, damaging populations occurred in only localized area.

Northern corn rootworm adults [*Diabrotica longicornis* (Say)] were quite abundant in many corn fields of the northern part of the state. Larval feeding on corn roots was rather general, although few reports of stalk lodging were received. Beetles feeding on corn silks were abundant enough in Jasper, Newton, and Benton counties to be of concern to hybrid seed corn procedures.

Southern corn rootworm adults (*Diabrotica undecimpunctata howardi* Barber) were abundant on many vegetable crops during August and September.

Corn leaf aphid [*Rhopalosiphum maidis* (Fitch.)]. Infestations were quite general and more aphids were found in late corn than in 1959, although their effect on the yield of this late corn was not apparent. Heavy infestations that were investigated showed few barren plants. However, fall estimates of losses were equal to those of 1959. Heaviest infestations were found in the north east part of Indiana. The infestations in the southern part of the state were higher but not severe. Sorghums in general were less infested than in 1959.

A billbug [*Calendra callosa* (Olivier)] was exceedingly abundant in a muck soil in Montgomery County planted to corn. The insects in early June had reduced the stand in one field by 50 per cent, while many of the surviving plants showed feeding injury. Fourteen acres of this field were disced after some experimental treatments had been made to the soil. Corn was replanted and on June 30 over 60% of the plants, regardless of treatment, showed leaf injury. This corn grew rapidly and most plants survived the feeding of the billbug.

Japanese beetle [*Popillia japonica* (Newm.)]. This insect continued to spread to many new areas of the state. Most infestations have been localized in areas adjacent to railroads, but the new one in Evansville extends from the Ohio River to a point north of the city. New county records consist of Vanderburg County (Evansville), Ripley County (Milan), Martin County (Shoals and Willowvalley), Daviess County (Washington), and Grant County (Marion). Other new localities within previously reported counties include: Ijamsville, North Manchester, Brimfield, and Milford Junction. In Newton County, where agricultural land is involved, the beetle population was higher this year, although not severe enough to cause damage to soybeans or corn.

Sorghum webworm [*Celama sorghiella* (Riley)]. This insect was observed in sorghum heads as far north as the Davis farm near Winchester, Indiana. No severe infestations were reported.

Tomato fruitworm [*Heliothis zea* (Boddie)]. Infestations in tomatoes were relatively unimportant. Corn, which is its preferred host, was in a

favorable condition to attract the moth and thus absorbed the bulk of the population.

The fruit fly (*Drosophila melanogaster* Meig.) built up rapidly during the latter part of the tomato season and developed one of our most severe infestations. Egg counts taken on cut fruit were nearly all positive with counts ranging up to 500 during the period of August 20 to September 15. This period was characterized by high humidity, heavy plant growth, and moderate temperatures.

Hornworms on tomatoes [*Protoparce sexta* (Johan.) and *P. quinquemaculata* (Haw.)] were very abundant with 80 per cent being *P. sexta.* Parasitism by *Apanteles congregatus* (Say) was so high, 90-95 per cent, in August that damage to the fruit and foliage was not as severe as in 1959.

Blister beetles (several species) were common on many crops. Some reports of localized abundance on tomatoes were received.

The striped cucumber beetle [*Acalymma vittata* (F.)] did more injury in 1960 than it has for the past several years. The spotted cucumber beetle (*Diabrotica undecimpunctata howardi* Barber) was not nearly as abundant on cucumbers as it was the previous year and did very little damage to cucurbits.

A variety of the pale striped flea beetle, the banded flea beetle (*Systena blanda* Melsh.) was much more abundant than normal in June when it damaged cucumbers severely.

The potato leafhopper [*Empoasca fabae* (Harr.)] was less abundant than usual on potatoes.

The squash vine borer [*Melittia cucurbitae* (Harr.)] was very abundant on certain varieties of squash, 50 per cent of the vines in some plantings being infested.

The squash bug [*Anasa tristis* (DeG.)] was again abundant throughout much of the state after being scarce for five years. In the pumpkin producing area of Jackson and Scott counties, it caused some losses. It was also quite abundant around Lafayette. Good growing conditions for cucurbits and the late development of the bugs probably forestalled serious losses in the Lafayette area.

The mint looper [*Rachiplusia ou* (Gn.)] was less abundant than in the past two seasons. A late infestation developed in August on second growth mint, but was of little economic importance. A number of parasites and diseases were found in fields in Jasper and Starke counties. Of these, a nuclear polyhedrosis virus disease was isolated from a large number of loopers collected from commercially grown mint. The disease was of epizootic proportion in the populations and was bringing about adequate reduction.

Both the imported cabbage worm [*Pieris rapae* (L.)] and the cabbage looper [*Trichoplusia ni* (Hbn.)] were destructively abundant on cabbage and related crops during July and August. Damage was especially severe from the looper, in spite of the parasite, *Apanteles glomeratus* (L.) which was abundant in many areas.

Meadow spittlebug [*Philaenus leucopthalmus* (L.)] was again the most serious insect pest on alfalfa and red clover. Infestations were very

heavy in eastern Indiana, particularly in counties along the Ohio border. Populations as high as three to five nymphs per stem were common.

Spotted alfalfa aphid [*Therioaphis maculata* (Buckton)]. This insect was not taken in Indiana in 1960 until October 5 when it was found in Floyd County west of New Albany. In an extensive survey it was not found anywhere else in the Ohio River Valley.

Hessian fly [*Phytophaga destructor* (Say)]. This insect showed a slight increase over 1959. Susceptible wheat averaged 15.3 per cent infested with a high of 40 per cent. Resistant varieties averaged 0.3 per cent infested.

Chinch bug [*Blissus leucopterus* (Say)] populations showed an increase over 1959 and insecticide controls were applied in a few localized areas in central Indiana.

Grasshoppers [*Melanoplus femur-rubrum* (DeG.), *M. differentialis*, and *M. bivittatus*] were more abundant and destructive than they have been for several years. Nymphal development was successful in lush fence rows, roadsides, and field margins. Migrations into crop land occurred in July and August causing considerable localized damage to corn, soybeans, and tomatoes. Adult *M. bilituratus* were collected in Vigo County during late June and in Tippecanoe County the first week of July.

Tree, Shrub and Forest Insects

Zimmerman pine moth [*Dioryctria zimmermani* (Grote)]. Infestations continue to be heavy in untreated pine plantings in northern Indiana.

European pine shoot moth [*Rhyacionia buoliana* (Schiff.)] had heavy overwintering populations in pine plantations of northern Indiana.

Bagworm [*Thyridopteryx ephemeraeformis* (Haw.)] populations were back to normal, important on both deciduous and evergreen plants.

Mimosa webworm [*Homadaula albizziae* Clark] was very serious on honey locust trees in central and southern Indiana. The insect continues to spread farther north in the state.

Elm leaf beetle [*Galerucella zanthomelaena* (Schr.)] was exceedingly abundant on Chinese elm trees in central Indiana. Nearly every Chinese elm tree was brown by late July.

The smaller European elm bark beetle [*Scolytus multistriatus* (Marsh)] continues its steady spread of the Dutch elm disease.

Cottony maple scale [*Pulvinaria innumerabilis* (Rathv.)] was abundant on silver maple in northern Indiana.

European pine sawfly [*Neodiprion sertifer* (Geoff.)] was again the most serious defoliator of pine plantations in 1960. The insect has now been reported from counties along the Ohio River, indicating that this insect now infests most of the state.

Fall webworm [*Hyphantria cunea* (Drury)]. The fall generation was unusually heavy in the most southern counties.

Catalpa sphinx [*Ceratomia catalpae* (Bdr.)] defoliated catalpa trees in the north central counties in August and September.

The walnut caterpillar [*Datana integerrima* G. and R.] defoliated walnut trees in northern Indiana in late August.

Eastern tent caterpillar [*Malacosoma americanum* (F.)] was commonly found on apple and black cherry trees in April and May.

The Judas tree leafhopper [*Erythroneura aclys* McAtee] was again abundant on redbud through the state. Most ornamental redbug trees were yellowed by mid-September.

The maple bladder gall [*Vasates quadripedes* (Shimer)] was unusually abundant on silver maple trees in the spring of 1960.

The honey locust pod gall [*Eotetranychus multidigitula* (Ewing)] was frequently reported deforming the foliage of honey locust trees in northwestern Indiana.

Locust leaf miner [*Chalepus dorsalis* Thunb.] was the insect responsible for the brown foliage of black locust trees in southern Indiana.

The hackberry lacebug [*Corythucha celtidis* O. and D.]. Severe infestations occurred in Madison, Fayette, and Tippecanoe counties.

Columbian timber beetle [*Corthylus columbianus* Hopk.]. This is a very important insect, in terms of forest economics. In total, its damage is inestimable; it is known that a one-third reduction in stumpage and finished lumber value is experienced due to the reduced quality caused by this insect. The insect is known throughout the southern one-half of the state and has been recovered as far north as Vermillion County.

Walking stick [*Diapheromera femorata* (Say)] is implicated in severe local outbreaks in northern Indiana. One such outbreak resulted in complete defoliation of from 10 to 20 acres of oak (probably bur oak, *Quercus macrocarpa* Michaux).

The symbiotic relationship between a leafroller and a webworm that resulted in maple blight as a major disease in Michigan and Wisconsin was discovered in Turkey Run State Park. The leafroller, *Acleris chalybeana* (Ferm.), provides the only possible oviposition site for the maple webworm, *Tetralopha asperatella* (Clem.), a colonial feeder.

An undetermined species of *Gracilaria*, another leafroller of sugar maple, is a new record for Indiana.

Livestock Insects

Face fly [*Musca autumnalis* DeG.] has replaced the house fly as the most important fly to the livestock industry. Populations in the northern half of the state built up to a high level in late June and remained high throughout the season. Counts were as high as 65 per cent per cattle face; increase in flies beyond this number resulted in their appearance on the cattle backs with counts up to 200 per animal. This fly is presently restricted in its habitat to about the northern half of the state. (See Pests of Man and Households)

House fly [*Musca domestica* L.]. This insect is now considered to be the second most important insect in dairy and beef herds. Populations were normal throughout the summer but increased to a rather heavy level in the fall.

Horn fly [*Siphona irritans* (L.)] was present in severe numbers on untreated cattle throughout the northern half of Indiana throughout the year. In the southern half, when the rains stopped the populations dwindled quite rapidly. Counts of 600 per animal were recorded on untreated cattle during August in central Indiana.

Horse flies [*Tabanus atratus* Fab. and *T. sucifrons* Marquart] were abundant in the northeastern portion of the state from the first week of

August through the first week of September. The number of "strikes" was about 20 per minute, a severe infestation but lower than that of the previous year.

Stable fly [*Stomoxys calcitrans* (L.)] was a serious pest locally in barns and loafing sheds where straw bedding was not changed frequently. Preceding late summer showers, this pest caused considerable annoyance to humans.

Cattle grubs [*Hypodermis bovis* DeGeer and *H. lineatum* (DeVilliers)] continue to cause moderate losses to the native cattle of Indiana.

Pests of Man and Households

Face fly [*Musca autumnalis* DeG.]. This insect of cattle has now become a serious threat as a household pest. Fall invasion of rural and suburban houses became a fact this fall with several homes having thousands of these insects congregating in attics and upstairs rooms. In one home in Warren County, thousands of flies, apparently seeking an overwintering locality, entered the attic, window frames, and rooms. In suburban houses, counts have been consistently high (30 to 40 per day) during the fall.

Cat flea [*Ctenocephalides felis* (Bouché)]. The essentially unbroken moist conditions this summer in many areas of the state have been conducive to flea development. Homes have been heavily infested, and control has been difficult except with organic phosphates.

Subterranean termites [*Reticulitermes* spp.]. Inquiries concerning these insects were numerous during the swarming season and have been less numerous but regular since that time. The trend toward increased interest in pretreatment noted in 1959 has continued.

Ticks—The brown dog tick [*Rhiphicephalus sanguineus* (Latrielle)] has been the subject of fairly regular inquiries since early July. The American dog tick [*Dermacentor variabilis* (Say)] has appeared to be less numerous this year.

The elm leaf beetle [*Galerucella xanthomelaena* (Schrank)]. From early February until mid-June inquiries were received regularly concerning the appearance of this insect in houses, due to the mergence of hibernating adults. Although populations seemed normal during the summer, there have been few complaints thus far this fall.

Field crickets [*Nemobius* sp.] have been unusually abundant this year due to desirable climatic conditions. From time to time they appeared by the hundreds on sidewalks outside of houses and stores.

Sap beetles [*Glischrochilus* spp.]. These insects have been particularly troublesome as uninvited guests when cooking is done outdoors. If the present trend toward "outdoor living" continues, these may well become one of our most troublesome pests.

German cockroach [*Blattella germanica* (L.)]. In 1959 this household pest was reported to be increasing in numbers and importance due to resistance to chlorinated hydrocarbons. Instances this year of suspected resistance to phosphates compound the problem and seem to indicate that it will continue to be the number one pest in this category.

Importance Rating

A rating is given of the ten most important arthropod pests in Indiana in 1960. In establishing this judgment, the following criteria were utilized: Damage or annoyance actually caused, newness of the situation requiring considerable investigation, and the extent to which measures were taken to prevent economic loss. The rating is:

1. Corn earworm
2. Subterranean termite
3. Face fly
4. Grasshoppers
5. Smaller European bark beetle
6. Codling moth
7. Cutworms
8. Cockroaches
9. European corn borer
10. Meadow spittlebug

Field Observations of Face Fly (*Musca autumnalis* DeGeer) in Indiana, 1960

R. C. Dobson and D. L. Matthew, Purdue University

Observations on the presence, abundance and habits of the face fly were continued through 1960. These insects were reported from the northern half of the state during the first week in June. The weather remained rather cool and wet for the remainder of the month and populations remained low, averaging 2-5 per animal. The first week in July, populations on the eastern side of the state increased to averages of 15 per animal. Numbers in the west and northwest were still fairly low. As the temperatures increased, so did the fly numbers. The third week of July they reached a maximum of around 70-80 per face in the northern and eastern parts of the state. With higher infestations, the flies dispersed to other parts of the body. Counts of flies over the entire animal frequently exceeded 200.

Observations made throughout the season indicated, as last year, that the most serious infestations of this insect were confined to the eastern and northern half of the state. Counts dwindled rapidly south of U. S. Highway 36 west of Indianapolis and U. S. Highway 52 east of Indianapolis.

Observations in 1959 indicated that cattle could avoid the annoyance from face flies by remaining in shade during the hot part of the day. However, in 1960, as populations rose in numbers, it became apparent that many of the flies were following the cattle into the shaded areas. In early September, face flies were taken from cattle in a barn in Tippecanoe County, an apparent reversal of the habit previously noted.

The authors (1) conjectured that these flies might invade homes and attics in cool weather. This statement was confirmed in Indiana this year. Several complaints from rural householders regarding large swarms of flies were reported to our offices. Investigation proved these flies to be adult flies apparently seeking shelter for the winter. Enormous numbers were observed crawling over the outside walls of the houses, seeking entrances under the eaves and around windows and doors. They congregated in unilayer groups in the evening and then clustered in masses several layers deep as darkness advanced and the temperature declined. Apparently activity is dependent on temperature since each afternoon as the temperature rose they became active, flying about and buzzing noisily.

Behavior. Other behavior characteristics of this fly were observed. The males were usually found during the day resting on fence posts, gates, and on leaves of trees near the cattle while the female flies were much more evident on the animals themselves. Counts taken from flies collected from the faces or backs of cattle showed a ratio of about 15 females to one male. Samples taken from fences and poles near the cattle showed males to be in the large majority.

The females seemed to be restricted to very fresh manure for oviposition. Manure freshly dropped was immediately investigated by the female and eggs deposited just beneath the surface. The ovipositor was forced below the surface and a dimple or very small opening remained

when the ovipositor was withdrawn. The females usually lay two to three eggs, each in its own spot in the fresh droppings and then moved on. After the eggs were deposited, a tiny stalk-like tube (a part of the egg-sac) protruded through the upper surface of the manure. This is the stalk referred to in earlier literature. Whether or not the female was capable of laying more mature eggs at one time has not been determined.

The face fly is a much noisier and more persistent insect than the house fly. The buzzing produced by the flies going into hibernation has been compared to that of a honey bee swarm. Flies confined to cages produce a very characteristic sound quite unlike the house fly.

In the early fall, this insect was noticed as a pest species annoying man. Swimmers, tennis players and golfers reported an annoying, clinging fly which was attracted to their skins but was not as easily driven off as the house fly. Examination of specimens showed them to be *M. autumnalis*. This habit was most apparent late in the season and in areas as far as two to three miles from livestock.

Literature Cited

1. MATTHEW, D. L. and R. C. DOBSON. 1960. *Musca autumnalis* DeGeer, A New Livestock Pest in Indiana. Proc. Ind. Acad. Sci. 69 : 165-66.

GEOLOGY AND GEOGRAPHY

Chairman: J. C. Hook, Indiana State Teachers College

Duncan McGregor, Indiana Geological Survey, was elected chairman for 1961

ABSTRACT

Micromagnetic Waves. Gerald J. Shea, Terre Haute.—The variable geomagnetic field has been known from early times. C. Gauss, about 1850, invented an instrument which would record these variations. The use of a modification of this instrument provided the following results:

1. Micromagnetic waves vary as to the season, the larger amplitude prevalent in the late spring and summer months.
2. A distinct change occurs before, during and after local storms.
3. The current affecting the instrument must be propagated by some solar mechanism in conjunction with the upper atmosphere of the earth.

Discovery and Evaluation of Water Resources By Aerial Photographic Method

ROBERT H. L. HOWE[1], West Lafayette, Indiana

This paper discusses the application of aerial photographic method to engineering projects related to the discovery and evaluation of water resources, particularly for areas where no hydrologic records are available. Aerial photographic method has been used in the investigation of various hydrologic problems including: (1) the study of surface drainage patterns, (2) the preparation of drainage maps, (3) the evaluation of a watershed, (4) the study of stream channel conditions, (5) the preparation of hydrologic or hydraulic models, (6) the identification and location of water-bearing formations, (7) the study of patterns of water-bearing formations, (8) the evaluation of ground water potentials, (9) the evaluation of ground water inventories and the preparation of ground water region maps, and (10) the prediction of ground water quality of an area.

The merits of using aerial photographic method have been recognized to be: (1) time-saving, (2) economy in terms of labor, material and equipment required, (3) sufficient reliability and accuracy when compared with other conventional methods, and (4) capability of meeting urgent needs for areas where records of water resources are not available for their development.

A number of equations has been derived or modified and used by the author in conjunction with projects for the discovery and evaluation of water resources by aerial photographic method (1):

1. Let A be the total area of the watershed, a_1, a_2, ... a_n the respective area of sub watersheds, having run-off coefficients c_1, c_2, ...c_n and average precipitation I_1, I_2, ...I_n. It is possible to estimate the total surface runoff Q_r of the entire watershed by means of the modified rational formula:

$$Q_r = C_1I_1a_1 + C_2I_2a_2 + \ldots\ldots\ldots + C_nI_na_n = \sum_{1}^{n} C_nI_na_n \qquad (1)$$

If the average precipitation I of the entire watershed is determined from isohyetal charts compiled from precipitation record, the average runoff coefficient C of the main watershed can be determined as follows:

$$Q_r = CIA = \sum_{1}^{n} C_nI_na_n \qquad (2)$$

---

1. The author wishes to thank C. H. Bechert, S. V. Griffith, Dr. Robert N. Colwell, Professor R. E. Frost, Professor H. R. Wilke and Professor D. E. Bloodgood for their respective direct and indirect assistance which has made possible the progress of various stages of research and investigation in relation to the development of this method of using aerial photographic technique for the discovery and evaluation of water resources

This paper is dedicated to Dr. Robert H. Randall, Honorary President of Pan American Institute of Geography and History, Washington, D. C. whose inspiration and advice have made possible the completion of this study by the author.

2. If the hydraulic head of the water discharging from the watershed is determined, engineers can appraise the hydro-electrical potential of the watershed by the following expression:

$$K_w = HQ_r'd/k_1 \qquad (3)$$

where K_w is the hydro-electric power in terms of kilowatts, Q_r' the flow rate, H the water head, d the density of water, and k, a conversion constant. When the daily surface runoff is estimated, the hydrograph of a watershed can be produced. This may lead to evaluating the annual total surface runoff, producing a mass hydrograph, and deriving a unit hydrograph for the area investigated. In this type of studies, the evaluation of C values relies greatly on the accuracy of the aerial photographic interpretation technique and the experience of the hydrologist-engineer.

3. The evaluation of the ground water (2,3,4) resources, or ground water potential, of an area can be deduced by means of an aerial photographic study together with some hydrologic, climatic, soil, vegetation, and geologic data. If the depth and areal boundary of the water-bearing formations are determined, the hydrologist-engineer can estimate the ground water storage of a particular area. In doing so, the specific porosity coefficients and infiltration capacities of the materials must be evaluated with reasonable accuracy. Let A be the total area under study with sub-areas a_1, a_2, $\ldots\ldots\ldots a_n$; D_1, d_1, $d_2\ldots\ldots\ldots d_n$ the respective depths of water-bearing formations or deposits; and P, p_1, p_2, $\ldots\ldots\ldots p_n$ the respective porosity coefficients. The total water-bearing capacity or ground water storage can be estimated from the following expression:

$$W = ADP = a_1d_1p_1 + a_2d_2p_2 + \ldots\ldots + a_nd_np_n = \sum_1^n a_nd_np_n \qquad (4)$$

4. If the precipitation and also the infiltration coefficients of respective areas are determined, it is possible to evaluate the ground water Q_g by the following equation:

$$Q_g = AFI = a_1f_1I_1 + a_2f_2I_2 + \ldots\ldots + a_nf_nI_n = \sum_1^n a_nf_nI_n \qquad (5)$$

Where Q_g may be the total ground water yield per year; A the total area; a_1, a_2 $\ldots\ldots\ldots$, a_n the sub-area; F, f_1, f_2, $\ldots\ldots\ldots f_n$ the respective infiltration coefficients; and I, I_1, I_2, $\ldots\ldots$, I_n the respective precipitation of each area.

5. If the transpiration and evaporation coefficient T of water in the area is determined, the hydrologist can also determine the water loss in this respect. The common relation of all the coefficients discussed in this paper is that their sum equals unity:

$$C + T + F = 1 \qquad (6)$$

In the discovery and evaluation of water resources, accurate values of all necessary coefficients must be determined. Aerial photographic method of studying an area can provide sufficient information for the derivation and determination of these hydrologic coefficients.

Aerial photographic method for the discovery and evaluation of water resources is still undergoing constant improvement along with photographic, instrumental and other technological progresses (5). Based on its merits, the horizon of using this method to serve mankind is indeed unlimited.

Literature Cited

1. HOWE, R. H. L.—"The Application of Aerial Photographic Interpretation to the Investigation of Hydrologic Problems"—Photogrammetric Engineering, Vol. XXVI, 1, March, 1960.
2. HOWE, R. H. L.—"Procedures of Applying Air Photo Interpretation on the Location of Ground Water"—Photogrammetric Engineering, Vol. XXIV, 1, March, 1958.
3. HOWE, R. H. L. et al.—"Application of Air Photo Interpretation in the Location of Ground Water"—JAWWA, 48, 11, 1956.
4. Manual of Photo Interpretation, American Society of Photogrammetry, Chapter 10, Paul J. Zinke, S. V. Griffith and Robert H. L. Howe, Contributing authors, 1960.
5. HOWE, R. H. L.—"Airphoto Interpretation of Water Resources" unpublished project report to Pan American Institute of Geography and History, 1958.

Settlement Changes Caused by Strip Coal Mining in Indiana

LEE GUERNSEY[1], Indiana State Teachers College

An examination of the United States Census Bureau map showing the percentage change in population by county during the 1950-1960 decade reveals that only 19 counties out of the 92 Indiana counties failed to increase in population during the last ten years (Figure 1). Of the 19 counties which experienced a population decrease, according to the 1960 preliminary Census data, all except four are located in Western and Southwestern Indiana. Oddly enough these four exceptions (Switzerland, Ohio, Union, and Jay counties) are all located next to the Ohio border.

All except four of the 14 counties wherein strip coal mining has occurred experienced a decline during the 1950-1960 decade (Table 1).

Table 1.—Population of Strip Mine Counties: 1960 and 1950
(Minus sign (—) denotes decrease)

County	1960 (preliminary)	1950	Percent increase 1950 to 1960
Total	391,093	399,220	—2.0
Clay	24,057	23,918	0.6
Daviess	26,467	26,762	—1.1
Fountain	18,549	17,836	4.0
Gibson	29,791	30,720	—3.0
Greene	26,129	27,886	—6.3
Knox	41,392	43,415	—4.7
Owen	11,421	11,763	—2.9
Parke	14,617	15,674	—6.7
Pike	12,731	14,995	—15.1
Spencer	15,986	16,174	—1.2
Sullivan	21,483	23,667	—9.2
Vermillion	17,531	19,723	—11.1
Vigo	107,668	105,160	2.4
Warrick	23,271	21,527	8.1

These four exceptions are Fountain, Vigo, Clay, and Warrick counties. Six of the county seat cities of the 14 Indiana coal-producing counties also declined during the last ten years. The six which declined are Boonville, Jasonville, Petersburg, Rockport, Sullivan, and Washington. (Table 2)

None of the four coal-producing counties which gained in population had an increase comparable to the State average of +17.8 per cent. The coal-producing county which had the largest relative gain was Warrick County which had a relative increase of 8.1 per cent and an absolute increase of 1,644 persons. The relative and absolute increases are due

1. The field research was aided by a grant from RESOURCES FOR THE FUTURE, to which grateful acknowledgment is made.

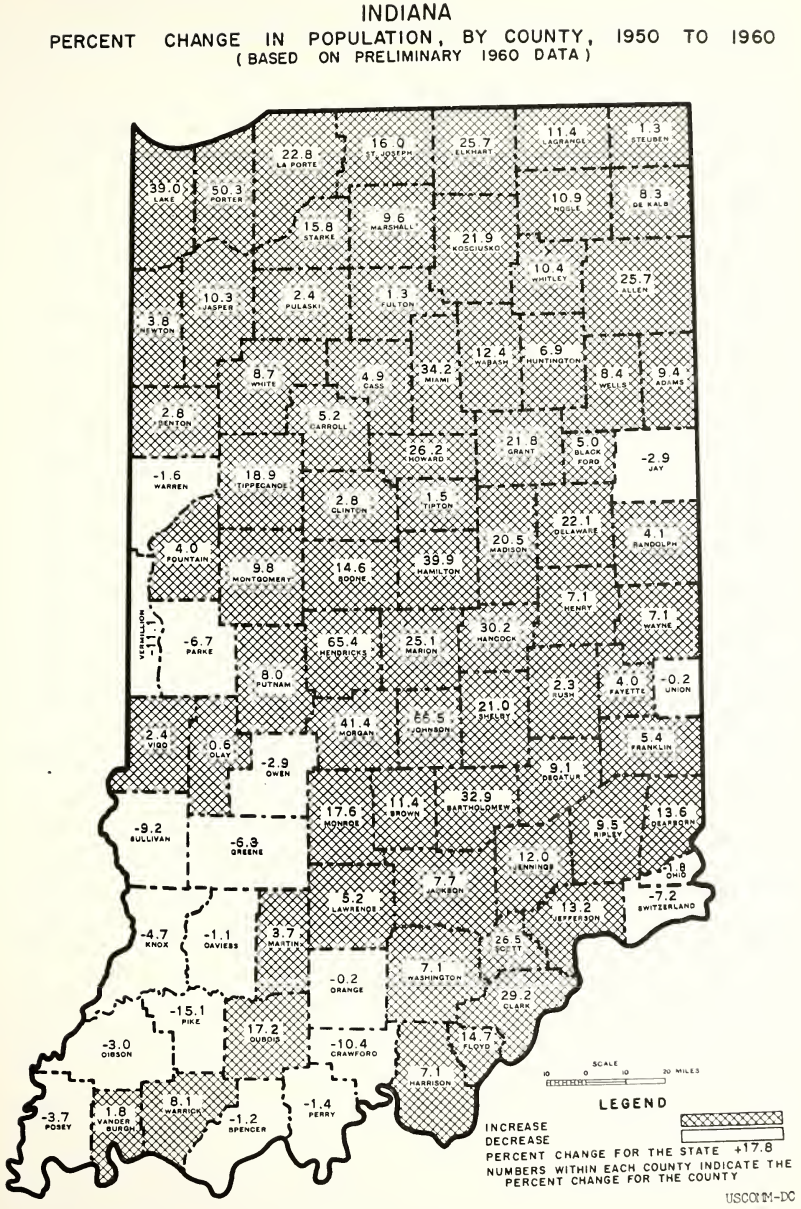


Figure 1

largely to the new Alcoa plant which represents the first step in large-scale industrial development in Southwestern Indiana outside of Terre Haute and Evansville.

Table 2.—Population of Strip Mine County Seats of 1,000 Inhabitants or More: 1960 and 1950

(Minus sign (—) denotes decrease)

Population of Strip Mine County Seats	1960 (preliminary)	1950	Percent increase 1950 to 1960
Bloomfield	2,198	2,086	5.4
Boonville	4,625	5,092	—9.2
Brazil	8,788	8,434	4.2
Covington	2,685	2,235	20.1
Jasonville	2,388	2,937	—18.7
Petersburg	2,923	3,035	—3.7
Princeton	7,846	7,673	2.3
Rockport	2,453	2,493	—1.6
Rockville	2,744	2,467	11.2
Spencer	2,486	2,394	3.8
Sullivan	4,934	5,423	—9.0
Terre Haute	71,786	64,214	11.8
Vincennes	17,939	18,831	4.7
Washington	10,754	10,987	—2.1

Vanderburgh and Vigo counties had the greatest absolute gains within Southwestern Indiana with increases of 2,891 persons and 2,528 persons respectfully. These absolute increases occurred because Evansville gained 11,857 persons and Terre Haute gained 7,572 between 1950 and 1960. In short, Warrick, Vanderburgh, and Vigo counties all have increased their industrial employment over their 1950 levels and each has experienced a resulting increase of population.

Settlements in Strip Mining Areas

There are no "mining towns" associated with strip mining. Strip mine labor is very mobile and most employees are local persons who have found employment with strip mine companies. Other miners commute from nearby towns which are usually located at a distance of not more than 20 or 30 miles away.

The closing of 153 underground coal mines since the 1920's has resulted in a fewer number of settlements in Southwestern Indiana. Strip coal mining is not conducive to the creation of any settlements since strip mines constantly migrate from place to place.

Once a large strip mine is opened, it commonly has a life span of 20 to 30 years. Of the 50 strip mines now operating in Southwestern Indiana, the local communities do not live in fear of a sudden shutdown. The end of strip mining in any area leaves neither ghost towns nor widespread unemployment. In contrast, both ghost towns and unemployment are common results of the closing of underground coal mines.

Semi-Urban Settlements

In strip-mine townships, the semi-urban settlements are concentrated near good roads, near urban areas, and usually have frontage on strip

mine lakes. Lakes formed among the spoil banks serve as sites for fishing, swimming, duck hunting and boating. A majority of the semi-urban settlements have their own private recreational facilities which are constructed around lakes left by the last box cut of the drag line.

In most cases, the coal companies retain ownership of the land after the coal is mined. They, therefore, can control to a considerable degree the location and number of semi-urban settlements. Several platted subdivisions are now being developed, and the selling of subdivisions is often a lucrative business. In these cases, it will probably expand in the future. It is estimated from field observations that between 500 and 800 semi-urban homes are located in the sections where strip mining has taken place in southwestern Indiana. But, exact numbers were impossible to correctly ascertain because of "no trespassing" and "keep out" signs or locked gates which are placed at the end of private lanes.

Impact of Strip Mining on Roads

The road pattern varies a great deal between the strip mined and unmined areas of Southwestern Indiana. The road pattern of the sections which have been strip mined is often oriented toward the preparation plant. In contrast, in the sections which have not been stripped, the roads generally follow the physical features or the section lines. The average mileage of roads per section in which strip mining has taken place was measured to be 2.8 miles, but in the sections where no strip mining has occurred there are only 2.2 miles of road per square mile.

Roads of the strip mine sections were often originally built for the hauling of coal to the preparation plant; and after the section is mined out, strip mine roads were commonly left as public roads. These county roads are well-built from slag and designed for heavy loads of coal. Thus, roads are of higher quality, road mileage is increased, but the road pattern is less efficiently arranged as a result of strip mining.

Farms and Farmsteads

Strip mining has encroached upon 1,310 farms in Southwestern Indiana, but 905 of the farm families have remained on the farm despite the strip mining (Table 3). Two factors are primarily responsible. First, strip mine companies do *not* generally strip completely contiguous sections of land in Indiana. Rather, strip mine patterns take on a disseminated distribution which leaves unmined lands within the sections for home sites. Secondly, the coal companies often leave the former land owner leveled lake sites by the box cut for his home. Strip mine lake sites in Indiana have no doubt attracted more families than the spoil banks have repelled.

Strip mining creates a "crazy quilt" pattern of fields (Figure 2). Most of the fields in the sections in which strip mining has occurred are irregular in size and shape. The traditional use of the land for agriculture is such that all available land suitable for cultivation is cropped, and normally spoil banks form the field boundaries. Some farmers rent land from as many as six different tracts in order to get sufficient acreages for cropland. Field boundaries are very irregular. The fields generally average from 10 to 15 acres in size with the fields being as large as strip mining will permit.

Table 3.—Impacts of Strip Coal Mining Upon Indiana Settlements

County	Acres of Land Strip Mined	Number of Farms Affected	Number of Farm Families Moved to Strip Mine
Clay	18,295	319	67
Greene	18,200	258	3
Pike	16,104	79	36
Warrick	13,265	142	42
Sullivan	8,303	145	67
Vigo	7,727	132	74
Knox	2,825	52	50
Owen	2,690	34	15
Vermillion	2,340	28	16
Daviess	2,218	40	13
Spencer	890	62	17
Parke	443	9	2
Fountain	380	5	3
Gibson	156	5	0
TOTAL	93,836	1,310	405

The number of farmsteads generally reflects the amount of strip mining that has occurred within each section. Strip mining has reduced the number of farmsteads by about 30 per cent, consequently, the more strip mining that occurs within one section, the fewer number of farmsteads that remain. Within all the townships of Southwestern Indiana in which strip mining has occurred, only one per cent of the farmsteads have been constructed since the land was stripped; and 69 per cent have remained unchanged.

Strip mining has caused 405 farm families who leased or sold their land for strip mining to move away from the area. They were seldom replaced by other persons. Farmsteads in the coal mining area have been reduced in number in recent years with a total of 393 having been torn down or abandoned in order to strip mine the coal. Furthermore, only 13 new farmsteads were constructed since the land was strip mined. From the farms on which the dwellings were torn down or abandoned, 405 families moved off farms which were strip mined. Thus, approximately 1,620 persons moved as a result of strip mining. There was about one family moved for each 231 acres of land strip mined.

The farms operating in the "coal mining area" are smaller than those in the "farming area" of Southwestern Indiana. Of the farmers interviewed, it was found that the average sized farm in the "coal mining area" was 92 acres as compared to 135 acres in the "farming area." These figures compare with 125 acres as the average sized Hoosier farm.

Farm operators in the "coal mining" area" are predominantly part-time farmers. Almost two-thirds of those interviewed worked off their

Figure 2. Patterns of fields created by strip mining

farm during 1959. Forty per cent had regular full-time jobs and farmed after completing work in various non-agricultural occupations. Strip mines provide employment to several hundred part-time farmers as truck drivers, shovel operators, mechanics, electricians, and ground men.

Conclusions

The comparison between the rural settlement patterns in all Indiana townships in which strip mining has taken place with those where no strip mining has occurred, demonstrates that strip mining causes some instability of settlements but not enough to have caused the population decline of 7,198 persons within Indiana's coal-mining counties. An analysis of the effect of strip mining on the rural settlements has revealed the following trends:

1. The number of individual farms decreased about 30 per cent after the tract of land was strip mined.
2. About 500 to 800 new semi-urban dwellings are now located on strip mined lands in Indiana.
3. A more irregular field pattern and smaller fields are created by strip mining, and single farm operating units are being changed into more complex multiple tracts.
4. Roads in the strip mined areas are of better quality; in addition, road mileage is increased, and a more random road pattern results from strip mining.
5. In 69 per cent of the townships where strip mining occurred, the rural farmsteads have remained unchanged, and in only one per cent of the farms affected, new buildings were constructed after the land was strip mined.

From the above data, it seems evident that strip coal mining is not the *direct* cause of the striking population decline of the Southwestern Indiana counties during the 1950-1960 decade. Despite the fact that 93,836 acres have been strip mined for coal in Indiana, only 405 farm families, or about 1,620 persons, have moved from the strip mined areas. At the same time, Hoosiers have found strip mine lakes to be desirable sites for several hundred semi-urban homes.

On the other hand, the *indirect* settlement changes caused by strip coal mining is considerably greater. For example, there are 93,836 less acres available as buildable land for industries or as cropland for agriculture. A total of 50,495 acres of cropland have been destroyed in order to mine the coal, and the value of the products from the strip mine acreages to date has been virtually nil and unable to support any settlements.

But, the lag between present industrial development and southwestern Indiana's industrial potential appears to be the *primary* reason for the general population decline rather than settlement changes caused by strip coal mining in Indiana. In short, the meager industrial development has not absorbed persons migrating from the relatively low-producing rural areas. Even though rural persons are reluctant to migrate, the lack of a dependable source of rural income has forced a total decline of 7,198 persons during the 1950-1960 decade in the counties wherein strip coal mining is located.

Geomorphology and Floods

M. C. Boyer, Indiana Flood Control and Water Resources Commission

Introduction

One of the most difficult problems facing the hydrologist and the hydraulic engineer in flood-protection work is the determination of the magnitude of peak discharges and the shape of flood hydrographs. These are essential to the design of flood-protection structures, including levees, floodwalls and reservoirs, for the determination of channel sizes and bridge openings, and for the establishment of house-floor elevations in urban developments.

The Surface Water Division of the United States Geological Survey maintains throughout Indiana and the Nation a network of stream-flow measuring stations, at which are recorded continuously river stages. By means of current-meter discharge measurements stage-discharge relations are developed and from these and the stage record the discharge hydrographs are computed. The problem is to extrapolate these records to streams on which there are no records, by a study of precipitation patterns, geomorphologic characteristics of the watersheds and statistical evaluations of flood frequency.

Chronology of Flooding

When precipitation occurs over a watershed a part is absorbed into the ground, a part is retained on the surface in puddles and ponds, and a part is intercepted by vegetation surfaces and the soil, to be evaporated during and following the storm. That part of the precipitation which is in excess of these demands finds its way into the streams and, if sufficiently large, produces a flood. This excess is referred to here as the runin.

During the progress of a storm the rate of runin increases to a maximum and then decreases at or shortly after the end of the storm. As the water flows over the ground surface and into the rills and small streams and thence to the larger creeks and finally down the main stream a part is retained as storage within the channels, to flow out after the peak. According to the equation of continuity

$$\text{Rate of runin} = \text{Rate of outflow} + \text{Rate of change in channel storage}$$

The rate of runin is primarily a function of the pattern of precipitation, with some modification by the geomorphologic characteristics of the watershed, the rate of change in channel storage is entirely modified by the geomorphologic characteristics of the stream channels. If it is possible to determine this latter relation, the data now being collected at stream-flow measuring stations may be extrapolated to ungaged areas and the characteristics of the flood hydrograph determined.

Illustrative Streams

Three Indiana streams of widely diverse geomorphologic characteristics have been selected to illustrate these effects on the flood hydrograph.

The Yellow River watershed above Plymouth drains the northeast portion of the Steuben Morainal Lake Section. Poorly drained muck

areas, lakes, kames, kettles, and eskers are common features. The surface drainage is very poorly developed, is dendritic, and is augmented by man-made ditches. The stream valleys are very young in age, having only recently been uncovered by the ice. The main tributaries exhibit narrow flood plains with very gently sloping valley walls and with relief not in excess of 30 feet. Shallow groundwater storage is very large.

The Raccoon Creek watershed above Mansfield drains a portion of the low, undulating Wisconsin Tipton Till Plain, which is broken with occasional morainic hills. The headwater creeks in southeastern Montgomery County flow mainly in Wisconsin glacial drift, occasionally crossing a bedrock outcrop. In Putnam and Parke Counties the bedrock exposures are much more frequent. The stream is in part preglacial, for which reason its valley width is most erratic. Raccoon Creek carried the outflow from glacial melting and undoubtedly experienced great floods during the severe storms which raged along the edge of the retreating ice. As a result, the valley is filled with coarse sand and gravel. Shallow groundwater storage is sizable, particularly along the upper reaches.

The Laughery Creek watershed above Farmers Retreat drains the east half of Ripley County, which lies in the southeast section of the Dearborn Upland. This creek and its larger tributaries are entrenched into Ordovician and Silurian limestones and shales. Impervious Illinoian glacial till overlies the bedrock and forms a relatively flat upland surface which extends out as long spurs overlooking the principal tributaries. The tributary streams are narrow, steep and V-shaped. The streams undulate back and forth between the narrow valley walls on shallow, coarse alluvium which covers the bedrock of the valley floor. There is practically no groundwater storage within the watershed.

Characteristics of the Flood Hydrographs

In Fig. 1 are shown the watershed outlines and channel slopes for the selected streams. It will be noted that the Yellow River is relatively wide as compared to its length, while Raccoon and Laughery Creeks are longer and narrower. The drainage areas are—Yellow River above Plymouth, 284 square miles; Raccoon Creek above Mansfield, 240 square miles; Laughery Creek at Farmers Retreat, 248 square miles. The average watershed falls are—Yellow River, 4 feet per mile; Raccoon Creek, 7 feet per mile; Laughery Creek, 8 feet per mile.

In Fig. 2 are shown time-intensity graphs of precipitation, runin, and outflow for intense storms over each of the three basins. The top graph gives the rainfall intensity, in cubic feet per second over the watershed, computed from data of the U. S. Weather Bureau. The middle graph shows the rate of runin, in cubic feet per second, computed by the equation of continuity. The lower graph shows the discharge past the gaging station, or the outflow from the basin at that point, also in cubic feet per second.

Attention is called to the following salient features: The precipitation rate over the Yellow River watershed during the flood of October 1954 reached a maximum of approximately 130,000 cubic feet per second. This was reduced by losses and modified by the geomorphological characteristics of the watershed to a maximum runin of 40,000 cubic feet per

FIG. 1

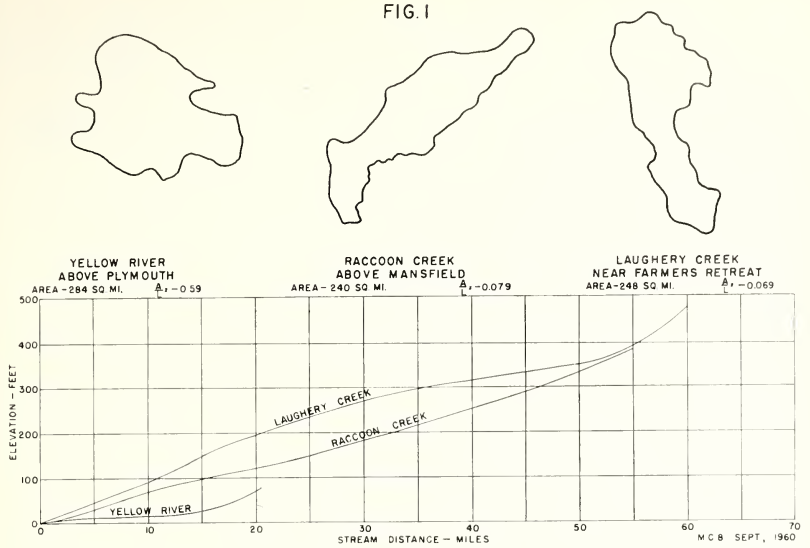


Figure 1

second. This was, in turn, greatly modified by the effects of channel storage, reducing the peak discharge at the gaging station to a mere 5,390 cubic feet per second.

In June 1957 the Raccoon Creek watershed was struck by a storm which had a maximum intensity of 140,000 cubic feet per second. This was modified by watershed characteristics to a maximum runin rate of approximately 110,000 cubic feet per second, which was in turn reduced to an outflow of 38,400 cubic feet per second by channel storage.

In January 1959 the Laughery Creek watershed experienced a severe storm. The maximum precipitation rate was 60,000 cubic feet per second, as a one-hour average. The maximum runin was over 100,000 cubic feet per second, which, in relation to the rainfall rate, seems somewhat anomalous. This will require further study. The peak outflow was 47,800 cubic feet per second.

The foregoing clearly shows the geomorphologic effects on the modification of storm precipitation. The losses were relatively small, varying from 0.9 inch in the Yellow River watershed to 1.3 inches in the Laughery Creek watershed. The channel storage, on the other hand, was much larger for Yellow River, than for either Raccoon or Laughery Creeks.

Geomorphologic Factors

The principal geomorphologic factors which modify the flood discharges of streams are the watershed area and shape, average watershed fall, the convexity or concavity of the basin, and the surficial geology. Curves of relation (Fig. 3) have been developed between peak discharge, watershed area, and watershed fall for several flood determinations on streams in central Indiana, made during the floods of May 1956 and May

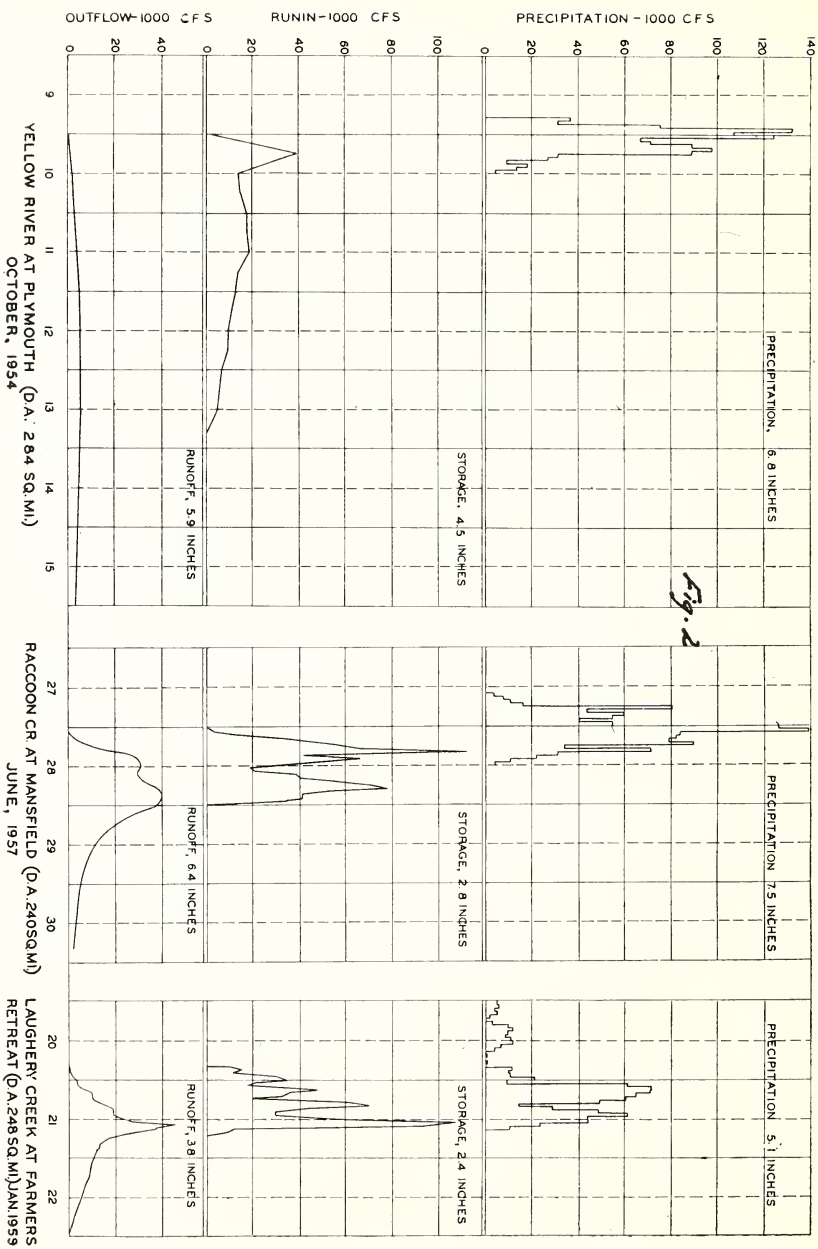


Figure 2

and June 1957. These have been very helpful in determining peak discharges for ungaged areas.

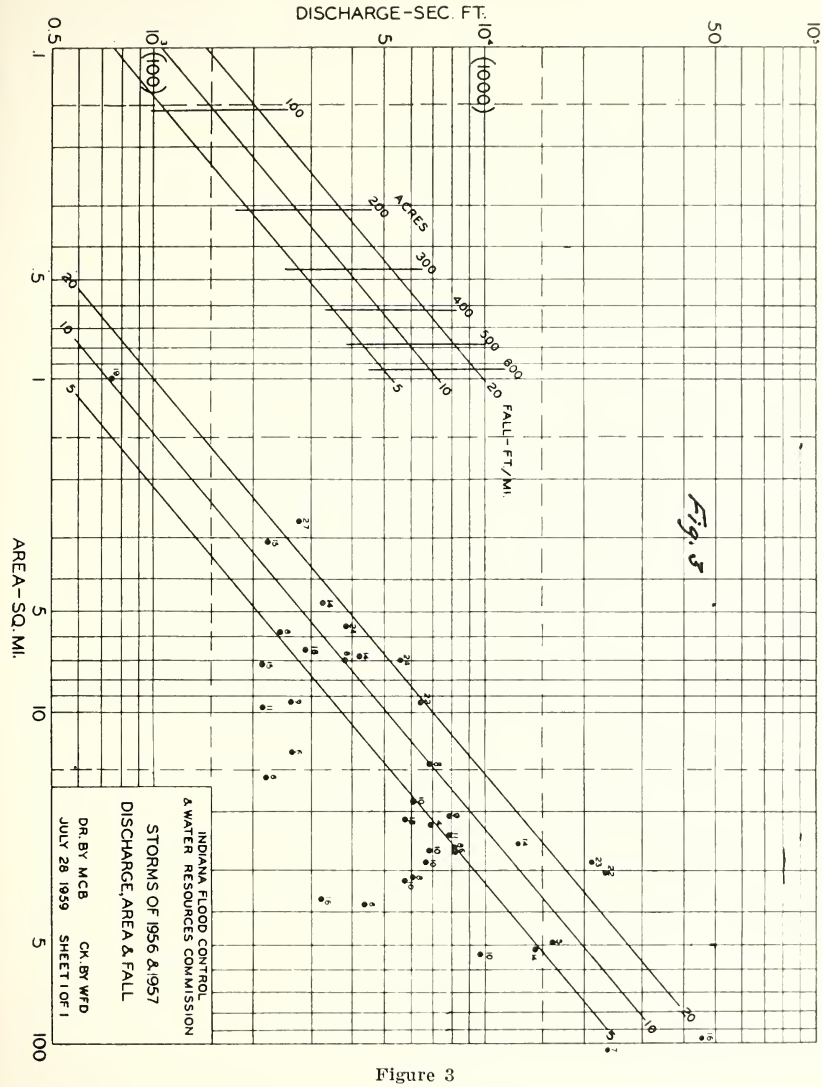


Figure 3

Studies are underway to develop dimensionless relationships between watershed falls, area, length, and shape, and the discharge characteristics of runoff, time to peak discharge, peak discharge, and the shape of the hydrograph.

The Monroe Reservoir: A Multiple Use Project

THOMAS FRANK BARTON, Indiana University

A Situation

The Monroe reservoir ground breaking ceremony took place on October 25, 1960, and there will be constructed within a few years thereafter the longest lake in Indiana. This lake will be approximately five times larger than the largest natural lake in the state, Lake Wawasee in Kosciusko County. The United States Army Corps of Engineers worked out the technical details. Now with the engineering plans crystallized, the public can be assured that the dam, spillway, and other structures will be technologically sound and efficient.

In sharp contrast with the progress made in mechanical engineering, the geographic, social and political engineering (so desperately needed for the success of the project) lag years behind. The people in the reservoir area, although not without some interest, seem to be more or less apathetic. Up to this time the greatest interest seems to be in real estate and in short-ranged personal economic gain rather than in the long-ranged public good. Some have the attitude that if a person hasn't lived in the county for several generations and does not own land, then he isn't qualified to discuss the numerous and serious problems and opportunities which construction of the lake would bring. At the present rate of progress, the reservoir will be filled with water and the country side surrounding it with land-use and other problems because our public officials (both elected and appointed) have failed to provide this and adjacent counties with county and township planning and zoning. The lake and rapid changes in land-use will come whether the public is ready for them or not. And if we fail in geographic, social and political engineering, this failure will rest more squarely on the shoulders of Monroe County citizens than upon the shoulders of anyone else. Not only is most of the reservoir and consequently the need for planning and zoning greatest in Monroe County, but if its citizens fail to adopt planning and zoning, people living in the townships of adjacent counties do not have the legal right to plan and zone unless their entire counties do so.

Will the economic and social development stimulated by the construction of this reservoir and the use of its water be wise or foolish, rational or irrational, financially sound or expensively wasteful?

Although many reports (some true, some half-true, and many false) have appeared in newspapers, newsletters, over the radio and by other means, by and large the general public is more or less uninformed, misinformed or bewildered about this project. The purpose of this paper is (1) to help clarify the major and minor uses of the reservoir and its water and (2) to point up the need for county and township planning and zoning.

Multiple-Use Reservoir

The two primary or major uses of the Monroe reservoir are (1) to help control floods on the Ohio River watershed and (2) to increase or augment the volume of low flow in Salt Creek below the dam and in the

East Fork of the White River. The reservoir's secondary or minor uses are (1) recreation, (2) restoration of fish and wildlife, and (3) water supply upstream from the dam.

Major Uses

Flood Control. About 58 per cent of the storage capacity of the Monroe reservoir at spillway crest is *allocated* to helping control floods on the Ohio River watershed (refer to Table 1). All other uses must yield to this primary one. For example, some people may wish to have the Monroe Lake cover 18,450 acres for 300 days out of the year so as to enjoy water sports on a large lake. However, nearly "full" lakes with water almost up to the spillways, contribute very little to flood control. Consequently, when the water in the Monroe reservoir gets higher than 538 feet above sea level, it will be drained through conduits and the surface of the lake again lowered to 538 feet.

The area of the lake between the 538 foot level and the spillway crest elevation of 556 is called the zone of expected frequent flooding or the flood control area (1). When the water stands at 538 feet, the reservoir's storage capacity is approximately 58 per cent empty as compared with its capacity at spillway crest (2). Studies based on water records for a 23 year period indicate that *flood water* would be stored in the reservoir "about 85 days in the year on an average." (3) In other words, the water is expected to be above the 538 foot elevation only 85 days in the year.

The lake will vary in size from 18,450 acres when the reservoir is full, water going over the spillway, to 10,750 acres when the surface of the lake is at "flood control" pool stage, reservoir elevation 538 (4). Consequently, 7,700 acres of land will be covered with water only during 85 days in the year. The other 280 days, or 77 per cent of the time, these 7,700 acres will be of necessity a big mud flat, perhaps covered in part in the years to come with some type of vegetation.

In times of exceptionally heavy rains, the reservoir stands ready to store 258,800 acre-feet of water and prevent it from rushing down Salt Creek into other rivers to help cause floods on the Ohio River watershed (Table 1).

Some people have the impression that the Monroe reservoir is being built primarily to protect the cultivated land in the Salt Creek valley below the dam. This is not true. It would be foolish to build a lake and flood 18,450 acres above the dam as well as subject an additional 2,250 acres (5) in the zone of infrequent flooding by the lake itself (between 556 and 561 foot elevations) in order to protect 7,800 acres in the Salt Creek valley below the dam. "Operation of the Monroe reservoir will provide almost complete protection to about 7,800 acres of land in the Salt Creek overflow area" (6) below the dam, but this protected acreage is only about 42 per cent of the size of the lake when filled to overflowing.

Rather than being constructed to protect only cultivated land in the Salt Creek valley, the Monroe reservoir is one of 85 surface storage projects being developed on the Ohio River watershed with the chief object to reduce the number, size and damage of the Ohio and even Mississippi River floods. (7)

Low Flow Augmentation. The second major use of the reservoir is to store water which can be used whenever *needed* to increase the flow of Salt Creek below the dam and, in turn, increase the flow of the East Fork of the White River. All the water stored between reservoir elevations 515 and 538 is *allocated* already for low flow regulation (refer to Table 1).

TABLE 1.

Pertinent Data About Monroe Reservoir[1]

	Elevation (ft. msl)	Area (acres)	Storage Capacity (acre-feet)
Silt pool	515	3,280	22,300
Low flow regulation pool.....	538	10,750	182,200
Flood control pool.....	556	18,450	441,000
Allocated to low flow regulation.	515–538		159,900
Allocated to flood control.....	538–556		258,800

1. The content of this table was made available by the courtesy of S. M. Bailey, Chief, Engineering Division, Corps of Engineers, United States Army, Louisville, Kentucky.

"A schedule of low flow regulation has not been finalized." (8) But the 159,000 acre-feet of storage between elevations 515 and 538 will be available to supplement runoff during periods of low flow due to fluctuations in the normal distribution of rainfall.

The state of Indiana will be primarily responsible for the use of water stored in the low flow regulation pool (Table 1). Should all the water allocated to low flow regulation be used for that purpose, there will remain in the reservoir only the water surface in the silt pool (Table 1). At such a time the water surface will be at reservoir elevation 515; the pool will cover only 3,280 acres, or less than 18 per cent of the area covered when the reservoir is at spillway crest; and the reservoir's storage capacity (at spillway crest) will be approximately 95 per cent empty.

Even the quantity of water in the silt pool will not remain constant. Silt will start to settle in the pool even before the lake is filled the first time. And if the surface of the reservoir is lowered artificially to the 515 foot elevation, nature through evaporation may lower it still further.

Low flow augmentation may be needed for (1) irrigation, (2) pollution abatement, and (3) domestic water supply and industrial water.

Approximately 20,000 acres of land above the dam will be taken permanently out of cultivation for flood control (18,450 acres covered by water at spillway crest and the area between 556 and 561 elevations in the zone of infrequent flooding). Agricultural production might be maintained or increased in Salt Creek valley by farming intensively the land below the dam. By using portable light-weight and inexpensive irrigation equipment, the rich flood plain soils could be placed under garden agriculture.

There is no serious pollution problem in the Salt Creek Valley today. "The present stream flow is sufficient to remove these wastes if adequate treatment is provided in accordance with existing legislation." (9) However, the prospects of new industry and suburban development along the Salt Creek and/or the East Fork, White River, may change this situation and create a need for more water for dilution. With water available, dilution becomes one of the cheaper methods of pollution control.

At the present there are no municipal demands for increasing the low flow of either Salt Creek or East Fork of the White River. In the Salt Creek watershed there is only one community, Oolitic, with a public water system. Its water comes from the Bedford water system. This city, in turn, gets its water from the East Fork of the White River above the mouth of Salt Creek. Some people believe "there is no foreseeable need for additional domestic water supply." (10)

Should Bloomington some day (for example, 15 years from now) need to supplement its water supply, other users may object, claiming they have a prior legal right to the water based on "priority of use."

The greatest demand for increased low water flow may come from industry such as mineral and stone plants and mills, potential wood-using and chemical industries, and thermal-electric plants. Although no thermal-electric generating plant, burning coal and generating electricity by steam, is located in the area today, one electric company has a site immediately below the confluence of the East Fork of the White River and the West Fork of the White River. (11)

"Present indications are that one and possibly two steam-electric generating plants with capacities of 1,300,000 kilowatts each may be built in this locality." (12) If two plants of such a size were constructed they would need an enormous supply of water for cooling purposes and/or expensive supplementary cooling equipment. For example, the Indiana-Kentucky Electric Corporation, Clifty Creek Station, Madison, Indiana, uses a total of "approximately 1,000,000 gallons of water per minute" (13) in generating 1,350,000 kilowatts. Furthermore, if these plants were built in the future on the White River generating 1,300,000 kilowatts each, nearly two million gallons of water per minute would be needed for cooling purposes, or as much water as could be obtained from both White Rivers. In addition to using all the water available in the two White Rivers for cooling purposes, expensive cooling machinery would be required to supplement the rivers. At the point where the electric company has acquired a site minimum water flow in the White River is only of sufficient size to supply a thermal-electric plant generating 600,000 kilowatts. (14)

The White River could be supplemented by water from the Monroe reservoir since Salt Creek flows into the East Fork of the White River above the potential electrically-generating plant site. According to tentative plans water will be drained out of the Monroe reservoir at the rate of "1,400 cubic feet per second for the period June 15 to September 15, and 1,000 cubic feet per second for the remainder of the year. . . ." (15) One thousand four hundred cubic feet per second is equivalent to approximately 628 thousand gallons per minute. If we add this potential low-flow augmentation of the Salt Creek to the natural flow in the East Fork of the White River, there would then be enough water to water-cool one plant

genetrating about 1,200,000 kilowatts. But if two plants of this size were built, a much greater supply of water from the Monroe reservoir would be needed. In fact, all the water above the reservoir 515-foot level is allocated to low-flow regulation. All of the water stored between reservoir levels 515 and 538 could be used for cooling electrical generating plants if no other use had a priority, or if a new restriction were not placed on how low the state of Indiana has a legal right to lower the level of the reservoir. In fact, the Monroe reservoir plus the White Rivers cannot furnish enough cooling water to supply several steam-electric generating plants capable of making a million kilowatts each. The amount of cooling water available may be a limiting factor in the design of these plants. Mr. J. I. Perrey, Chief Engineer for Indiana's Flood Control and Water Resources Commission, writes, "Cooling water will be required in large volumes by these plants and will be a limiting factor in their design." (16)

Minor Uses

Secondary Functions. Minor uses of Monroe Lake and its water will be (1) recreation, (2) restoration of fish and wildlife, and (3) water supply upstream from the dam.

Recreation

Unfortunately many people in the reservoir area have the impression that recreation is to become one of the major uses of the reservoir. According to present plans and published reports, approximately 95 per cent of the storage capacity of the Monroe reservoir at spillway crest has been allocated to flood control and to increasing the flow of Salt Creek during low flow periods (Table 1). The people may use whatever water is in the reservoir for recreational purposes as the surface level fluctuates between 556 feet at spillway crest to 515 feet at silt pool crest. Public facilities will be provided to help people obtain recreational benefits. But legally, according to priority water rights as now allocated, the reservoir can be lowered to the 515 foot level in order to increase the flow of Salt Creek below the dam. No one living today knows how often this will happen or how many days in the year the water will be at or near elevation 515.

For the first few years following the completion of the dam and the filling of the reservoir, recreation is expected to be the most important secondary use of Monroe Lake. Both the lake's surface and the land adjacent to its banks are expected to attract people seeking outdoor recreation. In fact, as soon as (and even before) the Indiana legislature passed the bill to support economically this project, real estate in the lake area started to change hands. After the necessary legislation passed, real estate speculation increased. To some the greatest interest in the lake has not been in its potential public contribution to the Salt Creek, East Fork of the White River and Ohio River watersheds, but what real estate would be involved. What land would the government buy? What land could speculators buy quickly from the uninformed rural folk to sell a few years later to recreation-hungry city dwellers and make a hundred or a thousand per cent profit or more? Who has the "inside information" as to how close one can get land to the water's edge? An interesting study might be made five years from now to learn who had the earliest and best informa-

tion about potential recreational real estate. But this study is limited primarily to the public recreational use of the lake and its environs.

According to Colonel Kenneth Marlin, Director of the Indiana Department of Conservation, his department will control the *use of the water surface* and will zone it for different uses. (17) The lake's surface will be divided into zones where each water sport of (1) swimming, (2) boating and skiing, (3) fishing, and (4) hunting will have priority during part or all of the year.

It is estimated that more people will spend more time swimming than in any other water sport. Fishing as an activity may rank second, but it may be overshadowed by boating and skiing. Until a decade ago, as far as boat traffic was concerned, some 25 million fishermen in the United States had the nation's waterways nearly to themselves. Within the last five years, however, with the nearly maintenance-free aluminum and fiberglass boats and reliable, big outboard motors, both boaters and skiers have just about driven the fisherman from some lakes. It is now estimated that there are currently more than two million water skiers. (18) It is obvious that water skiing and fishing in the same area at the same time or any time are not feasible; consequently, there is conflict of use. Skiing interferes with swimming and swimming interferes with fishing. The best way to reconcile these conflicts in use is by zoning parts of the lake for each.

But swimmers, skiers, and anglers must all have adequate access to the lake. Colonel Marlin believes that the Department of Conservation's greatest responsibility is to provide the public with such an access. (19) Tentatively, plans have been made to provide the public with eleven points of access. (20) Colonel Marlin revealed that the Indiana Department of Conservation is interested in two good beach areas on the reservoir and that this department will also acquire land for swimming, picnic areas, and public boat docks. (21)

The United States Forest Service, the largest land owners on the watershed (37,000 acres), will have nine miles of shoreline when the reservoir is filled. In July, 1960, Mr. Howard C. Cook, Supervisor of the Hoosier National Forest, reported that these nine miles will be developed for "forest-type" recreation such as camping, hiking, riding and swimming. These can be provided without interfering with the primary purposes of the Hoosier National Forest, namely (1) to produce lumber and wood products, and (2) to provide watershed protection. (22) Helping provide recreation has always been a secondary function of this forest. (23)

Restoration of Fish and Wildlife

As soon as water is impounded behind the dam and months before the reservoir is filled, the water will contribute to the restoration of fish, birds, and animals. One of the most severe limiting factors in the restoration of wildlife in southern Indiana has been the lack of an adequate water supply.

One hundred and fifty years ago southern Indiana had an abundance of various types of fish and wildlife. Some were consumed by the pioneers but the destruction of wildlife habitat more than the harvest of fish, fur-bearing animals and meat animals led to their dwindling in numbers. In quick succession the virgin forests were removed, the soil subject to ero-

sion, the water table dropped, springs went dry and the streams became polluted. (24)

If fish, birds, and animals are provided with water, food, shelter and nesting places and if breeding stock is present, the wildlife can restock the water and the adjacent land areas. Of course the Department of Conservation has the facilities with which to stock the lake with game fish. The 7,800 acre mud flat will be quickly occupied by birds that find such a habitat almost ideal for their type of life. Migratory waterfowl, especially ducks, may nest here if food, water and some protection is available.

One of the most controversial issues concerning the public use of the lake is the difference of opinion as to whether the upper reaches of the lake should be made into a waterfowl refuge. Some duck hunters are opposed to the establishment of a refuge because it would prevent hunting. Many nature lovers and those who prefer to hunt waterfowl with a camera rather than a gun believe a waterfowl refuge should be established or at least a study made by wildlife experts not employed by the Department of Conservation. These citizens believe that the department is "caught in a bind." Operation of the department depends in part upon the sale of hunting licenses and the hunters are reported to be a strong pressure group in the state. Other people maintain there would not be enough water in the upper reaches during long enough periods of time to establish a good refuge.

On March 2, 1960, at a public meeting in Bedford, Indiana, the Director of the Conservation Department announced the establishment of a duck refuge. On March 3, 1960, *The Daily Herald-Telephone* in Bloomington, Indiana, quoted the Director as saying that:

> . . . a large area of the eastern portion of the lake in Brown County will become a duck refuge. . . .
> . . . said that wild ducks will come naturally to the area and must be protected. He said he could not say whether duck hunting will will be permitted anywhere on the lake.
> No shooting or motor boats would be permitted in the duck refuge during the migrating season, which usually runs from about Nov. 1 to Jan. 1. (25)

However, by the time a public meeting was held in Bloomington on July 14, 1960, the duck refuge plan had apparently been dropped. The Director then announced a plan to:

> . . . restrict certain upper reaches in the shallows for hunting during the migratory fowl season. (26)

Water Supply Upstream from the Dam

If all the water stored between reservoir levels 515 and 538 and allocated to low-flow regulation is not needed, the surplus could be used for (1) domestic, (2) municipal, and (3) industrial purposes upstream from the dam.

Rural dwellers in the eastern half of Monroe County need water. Mr. Corry Alcorn, county agricultural agent, reported to the members of the Monroe County Development Committee at a meeting on September 23, 1960, that the region east of Indiana Highway 37 is largely barren of accessible underground water deposits. (27) Mr. Alcorn also reported that "ponds in the eastern part of the county retained water better than those in the western half." (28) The committee members present dis-

cussed "the possibilities of encouraging private financing for filtering plant and water system linked to the Monroe reservoir and of county-community financing. . . ." (29)

After the lake becomes a reality new recreational communities may require a source of water.

Industrial plants may locate adjacent to the reservoir above the dam in order to use water from the reservoir. However, the plants located upstream from the dam and taking their water directly from the reservoir will have no guarantee that water will be available between reservoir levels 515 and 538. These potential industries cannot rely on a daily water supply stored between these two levels for at least two reasons. First, the water may not be between these two elevations during part of the year. Consequently the water users who wish to take water directly from the reservoir will need to place the mouths of their intake water pipes in or near the silt pool. Therefore the water intakes in the reservoir will be located near the dam where the silt pool is located. Of course industrial users will want to locate their plants as near to their source of water as possible. If industry attempts to locate as near the silt pool as possible they will be competing for land desired by recreational interests. The best recreational facilities should also be located as near the silt pool as possible.

Second, although the water is there, the water users downstream from the dam may have prior legal water rights to it. Because of these conditions, most of the industrial plants will likely occupy sites down stream from the dam.

Conflict in Uses

The State of Indiana may become, if it is not already, involved in "water rights" and "priority of use."

When man attempts to use a resource or project for several purposes, conflict in use develops unless allocations and priority of uses and restrictions on such are well clarified from the beginning. Although the State of Indiana is paying for 54.1 per cent (30) of the project's cost, about 58 per cent of the reservoir's storage capacity is "earmarked" for flood control. Storage in the Monroe reservoir between elevations 538 and 556 feet is legally reserved for flood waters and this part has a storage capacity of 258,000 acre feet. (31) The public should be informed that except for about 85 days in the year (or less than a ratio of one day in four) the water will not be above the 538 foot level. The reservoir or lake will cover only 18,450 acres during exceptionally heavy rains and for a few weeks after. Although the public is not aware of these statistics, it seems to generally accept the fact that the use of the reservoir is chiefly for flood control.

Apparently the public does not know or does not understand that an additional 37 per cent of the reservoir's storage capacity is allocated or "earmarked" for increasing the size of the minimum flow of Salt Creek below the dam. This means that the state of Indiana not only has the right and the responsibility, but it may be legally obligated to drain out all the water in the reservoir above the 515 foot level if a user (such as a city or industry) downstream from the dam needs and requests the water. Of course, if all the water allocated for increasing the low-flow of Salt Creek were used for this purpose, only a shallow pool covering 3,280 acres

would remain in the reservoir; the mud flat would cover 15,170 acres and the storage capacity of the reservoir at spillway level would be about 95 per cent empty. The Army Corps of Engineers has called attention to the fact that a large demand for increasing low flow would adversely affect the recreational use of the reservoir. Their report reads:

> . . . major drawdown of the permanent pool for low-flow regulation in the streams below the dam would reduce the potential recreational value of the reservoir pool; although on the other hand, increased stream flows would enhance fishing values in the streams below Monroe Dam. (32)

Along the shoreline people on a hot summer day subject to mounting rage, gazing out of their expensive cabins, unable to go swimming, boating or fishing because they cannot reach the shallow pool of water across a broad 15,170 acre mud flat, may not be in the mood to be placated when told that there are more fish in the streams below the dam because of the water drained from the reservoir for low flow augmentation. In their anger some may reply that "naturally the regulators of the conduits had to let some of the fish through with the water because there isn't enough oxygen left in the silt pool to keep the fish alive." If the water in the reservoir were lowered to the 515 foot level very many times in a year and should the water stand at or near silt pool stage for many days in succession, then recreational real estate values might well come tumbling down. What organization, institution or agency would want to invest thousands of dollars in recreational facilities near a reservoir which *may be* drained about 95 per cent dry in order to increase the flow of Salt Creek below the dam.

At the present the silt pool covering 3,280 acres is the only part of the reservoir "allocated" for recreation and the restoration of fish and wildlife.

If the people truly understood this situation, some people would demand that the Indiana legislature set up some type of restriction on the use of water for low-flow regulation in order to protect the recreational rights of the people. Should part of the reservoir storage be legally allocated to recreation? Or is it too late to get such an allocation?

It also becomes rather obvious why there may be delays in a commitment to the establishment of a Migratory Water Fowl Refuge on the upper reaches of the reservoir. A waterfowl refuge without water for long periods of time wouldn't be much of a refuge.

Perhaps it is not too late to allocate part of the Monroe reservoir's storage capacity for recreation. But shouldn't the people, particularly those interested in recreation, be informed or act quickly to have their rights safeguarded before thousands of dollars are invested in recreational facilities built on the false assumption that they will have available for their use throughout the year a 10,750 acre lake? Unfortunately the drawdown of the reservoir for low flow augmentation would coincide in time (during the warm summer months and early fall) when expected potential recreational use would be at a peak.

In summary, as of October 1, 1960, when this paper was completed, it appears that the recreational use of the reservoir has no protection or assurance under present laws or policies. This lack of protection (unless changed) may well influence the Federal government's reactional policy

and expenditures on the land managed by the Hoosier National Forest in the Monroe Reservoir area.

Planning or Waste

Can the people in Monroe, Brown, Jackson and Lawrence counties who in the past, either by indifference or obstruction, opposed county (or rural) planning and zoning reverse their position now and adopt zoning regulations that would control future land use development around the Monroe reservoir? In the next ten years will the development around this reservoir prove that local and state planning is superior to Federal planning?

Up to October 1, 1960, when this paper was completed, we seem to have failed.

(1) We have failed to follow the planning suggestion made in March 1960 by both Robert W. Kellum, executive secretary of the Indiana Flood Control and Water Resource Commission, and Colonel Kenneth Marlin, Director of the Indiana Department of Conservation. These two men in public addresses in Bedford emphasized the fact that one of two uppermost problems regarding the Monroe reservoir would be ". . . zoning of the entire reservoir area to assure orderly growth in the future after the lake becomes a reality." Mr. Kellum assures me by letter that in this suggestion he meant the countryside as well as the lake's surface should be zoned.

Mr. Kellum also suggested at the March, 1960, meeting in Bedford that "a four county meeting of county and township officials from Monroe, Lawrence, Brown and Jackson counties be held for the purpose of discussing zoning."

To date such a meeting had not been held.

(2) The citizens in Monroe County have also failed to (a) make an inventory, (b) produce a master plan, and (c) zone the use of land in Monroe County. In January, 1949, Monroe County organized a Planning Commission. For eleven years this Planning Commission successfully (a) blocked the city of Bloomington from planning and zoning a two mile fringe area around the city, (b) ignored county problems, (c) shelved possible planning issues, and (d) refused to take action to secure money that would help to operate efficiently a positive planning and zoning pattern.

However public pressure grew so strong in favor of planning during the first six months in 1960 that the Monroe County Planning Commission in July agreed to include in its 1961 budget a request for $12,000 to pay a professional agency to make an inventory and draw a tentative master plan for county zoning. The Board of County Commissioners later cut this request almost in half. In spite of this, the board for the first time in 12 years at least appropriated enough money so the Planning Commission could take some positive action.

(3) We have failed to complete comprehensive state planning. For example, it is not yet known whether "a migratory waterfowl refuge" will be established on the Monroe reservoir or not. Mr. Kellum assured me by letter that:

> There is no answer that will be satisfactory for (waterfowl refuge) use at this time because this is being studied in compre-

hensive planning. This is a prospect, of course, but to say "yes" or "no" merely causes embarrassment in the study phases. No answer is possible now. (33)

Thus we see that geographic and political engineering for the reservoir and the surrounding country-side lags dangerously behind mechanical engineering. Can the public be alerted in time? If a study of the planning phases of the Monroe reservoir were made in 1970 or 1980, would it indicate that local and state planning were superior to Federal planning?

Literature Cited

1. United States of America, House Document No. 192, 85th Congress, 1st Session, *Monroe Reservoir, Salt Creek, White River Basin, Ind.*, Washington, D. C., Government Printing Office, 1957, p. 3.
2. Personal letter from S. M. Bailey, Chief of the Engineering Division, Corps of Engineers, United States Army, Louisville, Kentucky, December 7, 1959.
3. *Ibid.*
4. *Ibid.*
5. Personal letter from S. M. Bailey, Chief of the Engineering Division, Corps of Engineers, United States Army, Louisville, Kentucky, September 29, 1960.
6. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.*, p. 30.
7. OAKLEY, BILL, "Army Engineer Shows Lake's Physical Look," *Daily Hearld Telephone,* Bloomington, Indiana, July 15, 1960, p. 1.
8. *Op. cit.*, Bailey, December 7, 1959.
9. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.*, p. 28.
10. *Ibid.*
11. *Ibid.*
12. *Ibid.*
13. Personal letter from Ralph D. Dunlevy, Plant Engineer, Indiana-Kentucky Electric Corporation, Clifty Creek Station, Madison, Indiana, August 26, 1960.
14. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.*, p. 28. Also see pp. 45-46 in *Report of Investigation Monroe Reservoir Salt Creek near Harrodsburg, Indiana for Flood Control, Increasing Low Flow and Allied Purposes,* prepared and published by the Flood and Water Resources Commission, Indianapolis, Indiana, December, 1956.
15. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.*, p. xix.
16. *Op. cit., Report of Investigation Monroe Reservoir Salt Creek near Harrodsburg, Indiana for Flood Control, Increasing Low Flow and Allied Purposes,* p. 37.
17. *Daily Hearld-Telephone,* "Plenty of Problems Ahead for Proposed Monroe Lake," March 3, 1960, p. 1.
18. SPORTS FISH INSTITUTE, "The Problem of Recreational Water Conflicts," *SFI Bulletin,* Washington, D. C., August, 1960 (No. 105), p. 1.
19. *Op. cit.*, "Plenty of Problems Ahead for Proposed Monroe Lake."
20. *Daily Hearld-Telephone,* "To Bring Tourist Boom," July 15, 1960, p. 1.
21. *Op. cit.*, "Plenty of Problems Ahead for Proposed Monroe Lake."
22. BARTON, THOMAS FRANK, "The Hoosier National Forest," *Indiana Academy of Social Science Proceedings, 1956,* New Series, Volume III, p. 88.
23. *Ibid.*, p. 91.
24. BARTON, THOMAS FRANK, "The Sewer or Waste Disposal Use of the Ohio River," *Journal of Geography,* 1960, Volume 59, pp. 326-336.
25. *Op. cit.*, "Plenty of Problems Ahead for Proposed Monroe Lake."
26. *Op. cit.*, "To Bring Tourist Boom."
27. *Daily Hearld-Telephone,* "New Lake Seen As Solution to Water Shortage," September 24, 1960, p. 1.

28. *Ibid.*
29. *Ibid.*
30. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.,* p. 3.
31. *Op. cit.,* Bailey, December 7, 1959.
32. *Op. cit., Monroe Reservoir, Salt Creek, White River Basin, Ind.,* p. 23.
33. Personal letter from Robert W. Kellum, Executive Secretary, Flood Control and Water Resources Commission, September 28, 1960.

HISTORY OF SCIENCE

Chairman: FAY K. DAILY, Butler University

T. G. YUNCKER, DePauw University, was elected chairman for 1961

Biographical Sketches of Indiana Scientists Not Listed Elsewhere, I

WILL E. EDINGTON, DePauw University

This is the first of a series of articles devoted exclusively to the presentation of biographical sketches of Indiana scientists whose work was completed in the nineteenth century or the early part of the present century. It is hoped that others will take up the work and thus make the Proceedings of the Indiana Academy an authoritative source for this biographical material. The source for most of this material is to be found only in newspaper obituaries, college yearbooks, county histories, memorials published at the time of decease, brief sketches in professional journals, and through copious correspondence with close relatives of biographees and others who might possess such information. Obviously such sources are not readily accessible and any one source is rarely complete or comprehensive. The value of the material is historical and should be of use in evaluating the role of science in the development of our educational institutions and our natural resources. No claim is made for completeness for at this late date completeness can come, if ever, only through the interest and cooperation of others who are aware of otherwise inaccessible information.

At the time that these men were active, Indiana colleges and universities had small enrollments and, individually, relatively were unimportant. In 1890 Indiana University had an enrollment of 321 students, not including preparatory students, and it was 1898 before the enrollment exceeded one thousand students when 1,049 were enrolled. Similarly Purdue University had an enrollment of 419 non-preparatory students in 1890 and its enrollment exceeded one thousand in 1900 when 1,012 were enrolled. The enrollments of the other colleges of the state were smaller in 1900. Also Volume I of "Who's Who in America" was published in 1899 with only 8,602 sketches, and Volume I of "American Men of Science" appeared in 1906 with about 4,000 sketches, so that most of the men considered here had virtually completed their careers before these directories became comprehensive enough to consider them.

THOMAS GREENE ALFORD. He was born at Alfordsville, Daviess County, Indiana, March 26, 1852, and died in Lagrange, Illinois, March 25, 1919. He was educated in the district schools and his family moved to Bloomington in 1866 where he entered Indiana University and received the A.B. degree in 1871. He taught three years in the district schools in Daviess County and then attended the Indiana State Normal School at Terre Haute for one term in 1874-75. He began teaching in high school and in 1881 he was Principal of Vevay High School and Superintendent of the City Schools of Vevay, Indiana. In 1888 he was Assistant Principal

of Indianapolis High School under Superintendent Lewis H. Jones, and he also received the A.M. degree that year. He came to Purdue in 1892 as Professor of Mathematics and held that position until his retirement in 1917. In 1913, at the request of President Stone, he began devoting half of his time to the student YMCA. He was appointed in January, 1917, Executive Secretary of the Purdue Union Committee to interview Purdue alumni and friends and solicit funds for a Purdue Student Union Building. He began work in September, 1917, but declining health prevented his doing a great deal, and he went to live with his only child and daughter, Muriel J. or Mrs. J. W. Dietz in Lagrange, Illinois. He was married to Miss Effie Wilson in 1881, and she died in 1899. He held membership in the Indiana State Teachers Association, Indiana Historical Society, Scabbard and Blade, and the Irving Literary Society. He was a 32° Mason and a member of the Scottish Rite and Mystic Shrine, and the Presbyterian Church. He became a member of Phi Kappa Psi while a student at Indiana and he helped to organize the Purdue Chapter in 1901. He set up the Alford Trophy, a Cup, in 1912, to be awarded each semester to the fraternity chapter on the Purdue campus having the highest scholarship. His Award was retired in 1920, after his death. (Principal source: Purdue Exponent, March 26, 1919.)

JASPER ASAPH CRAGWALL. He was born near Bean Station, Grainger County, Tennessee, on April 23, 1867, and died at Bean Station, October 29, 1937. He graduated from Vanderbilt University in 1886 with a degree in engineering and spent the next five years as a civil engineer on the Nashville, Chattanooga and St. Louis Railroad. He then took up teaching and in 1895 became Head of the Department of Mathematics in the Nashville, Tennessee, High School. In 1901 he came to Wabash College as Professor of Mathematics. During his six years in Nashville he received the Master's degree in mathematics and physics at Vanderbilt. At Wabash he also became Registrar in 1906 and became Chairman of the Faculty Athletic Committee through which he rendered outstanding service in insisting on and securing higher standards of sportsmanship in intercollegiate athletics. In 1919 he took a year off to go into business. After his return to Wabash he became a victim of arthritis which forced his retirement as Registrar in 1922. After spending two winters in Arizona and making other journeys seeking relief he was forced to resign in 1929. After his retirement he returned to his Tennessee home and then spent considerable time before his death seeking relief in the dry climate of Arizona. In 1932 he was able to attend the Wabash Centennial celebration at which time Wabash honored him with the Sc.D. degree. Professor Cragwall was a charter member of Mathematical Association of America which was organized in January, 1916. He was also a member of the Crawfordsville Rotary Club and the Presbyterian Church. He was the father of four children. An excellent and popular teacher, he was highly regarded by Wabash alumni and was considered a "Grand Old Man of Wabash." (Sources: Indianapolis Star, October 31, 1937; Osborne and Gronert, Wabash College, The First Hundred Years, 1832-1932; Correspondence.)

RUFUS HAYMOND. He was born in Clarksburg, Virginia (now West Virginia), on June 5, 1805, and died at Brookville, Indiana, July 29, 1886.

He came to Brookville in 1826 and was a practicing physician and a member of the National Association of Physicians. He entered actively into the civic affairs of Brookville and was President of the first Board of Trustees of the Corporation of Brookville. He served Franklin County as Clerk and also as its Representative in the State Legislature. He was deeply interested in nature and was a keen, careful observer of mammals and birds, noting their species, habits, abundance and distribution. His paper on "Birds of Southeastern Indiana," listing 138 species, was published in 1856 in the Proceedings of the Academy of Natural Sciences of Philadelphia. He served as an Assistant Geologist to State Geologist E. T. Cox and in the Eleventh Annual Report of the Indiana State Board of Agriculture and the Report of the State Geologist for 1869, Dr. Haymond published three reports, one on the geology of Franklin County, and two papers, "Mammals Found at the Present Time in Franklin County," and "Birds of Franklin County, Indiana." He gave lectures on natural history and influenced many young men to study nature, two of whom were Amos Butler and E. R. Quick, both of whom were active in founding the Brookville Society of Natural History in 1881 and later, in 1885, the founding of the Indiana Academy of Science. His last paper was published in Volume 13, The American Naturalist, 1870, "On the Drumming of the Ruffled Grouse." Dr. Haymond was recognized nationally as a student of vertebrate zoology and one of the pioneer naturalists of the Ohio Valley. (Sources: E. R. Quick, Bulletin of the Brookville Society of Natural History for 1887; W. S. Blatchley, B. W. Evermann, Vol. 26, Proc. Ind. Acad. of Science for 1916; Amer. Naturalist, Vol. III, April, 1869.)

FRANK RAWDON HIGGINS. He was born in Wolfville, Nova Scotia, on February 4, 1869, and died in an automobile accident at Brutus, Michigan, August 12, 1936. His father was Professor of Mathematics in Acadia College, a Baptist college in Wolfville. F. R. Higgins received the A.B. degree at Acadia College in 1891 and the A.M. degree from Cornell University in 1894. The following year he taught in a boys' school, and entered the University of Chicago for graduate study in the Fall of 1895. He came to the Indiana State Normal School, now the Indiana State Teachers College, Terre Haute, Indiana, in 1896 as Assistant Professor of Mathematics and retired as Emeritus Professor of Mathematics in 1935, but he continued to teach some the next year. He became a citizen of the United States some time before 1905. He did some research work at the University of Colorado in the summers of 1928 and 1930. Professor Higgins was married to Miss Hope Vickroy, of Terre Haute, in 1905. He was a quiet, retiring man but an effective teacher who, together with Professors Kelso and Baxter as his colleagues, influenced a number of men to do graduate study in mathematics, a number of whom became prominent educators. Professor Higgins was interested in politics. He enjoyed making furniture in his woodworking shop and he had his own darkroom for developing the many pictures he took on summer vacations. He was a member of the Indiana Academy of Science from 1898 to 1912 and a charter member of the Fort Harrison Country Club. He was active at one time in the Young Business Men's Club in Terre Haute. At the time of

his death he was working on a textbook in mathematics. (Sources: Terre Haute Star, August 14, 1936; Mrs. F. R. Higgins; Personal acquaintance.)

ALEXANDER KNISELY. He was born on a farm a half mile west of Columbia City, Indiana, on December 12, 1851, and he died on this same farm on September 29, 1931. He was a sickly child and as a result he read a great deal and also showed unusual ability in mathematics. He attended Valparaiso University, at that time primarily a private normal school, and received the B.S. degree, with a fine business training but little training in mathematics. In the Fall of 1879 he began teaching school at Mason City, Illinois, where he remained until 1885 when he returned to Columbia City to become County Superintendent of the Whitley County Schools. He served as County Superintendent for six years and then became associated as general agent with Warder, Bushnel and Glessner Company, manufacturers of Champion Mowers and Binders. He married Miss Mary Elizabeth More in 1892 and they lived in Lafayette. In 1896 they moved to Logansport, which was nearer the center of his territory. When his company became a part of the International Harvester Company about 1901 Mr. Knisely retired to his farms in Columbia City. During the next twenty years he refused the presidency of a bank, the managership of a mill, and the candidacy for County Treasurer, so that he could manage his farms and devote considerable time to problem solving which he loved. However, he made real estate appraisals and served on various county boards and commissions for road construction and other projects. In 1921 when the Farmers Mutual Insurance Company of Whitley County was having financial difficulties he was asked to take charge and he spent the last ten years of his life as its Secretary and Director. Mr. Knisely was an outstanding citizen of Whitley County and headed its Corn Exhibit for ten years. He was a 32° Mason and member of Eastern Star. For years he served as treasurer of the Columbia City Library Board.

In 1891 when the New York Mathematical Society opened its membership on a national basis, Alexander Knisely was one of nine Indiana men to join. The total membership of the Society at that date was 227. The Society became the American Mathematical Society in 1894 and is now one of the leading and largest mathematical societies in the world. Mr. Knisely was a member until his death. Likewise when the Mathematical Association of America was founded in January, 1916, Mr. Knisely was a charter member and kept his membership to the end. Here was a man with an intense love for mathematics who doubtless possessed considerable innate mathematical ability, but who received little encouragement to pursue the subject. Occasionally some of his solutions to problems were published. That he possessed unusual ability did not go entirely unrecognized for in 1927 Professor Joseph K. Hart of Columbia University and a native of Columbia City dedicated his book "Light from the North" to Alexander Knisely. (Sources: Reports of State Superintendents of Public Instruction, 1885-91; Mathematical Society Directories; Ex-Governor Ralph F. Gates; Daughter, Mrs. Ilene K. Winkelman, Akron, Ohio.)

REUBEN S. LAWRENCE. He was born in Canaan, Connecticut, on September 20, 1858, and died at Hanover, Indiana, January 30, 1919. His

family moved to Sandisfield, Massachusetts, when he was one year old and then to Wichita, Kansas, in 1872. He graduated from Wichita High School and completed his preparation for college under Rev. Darwin Cook, of Merryall, Pennsylvania, a Presbyterian minister noted for the large number of boys he prepared for successful college careers. He entered Princeton University and received the A.B. degree in 1885 and the A.M. degree in 1887. Following his graduation from Princeton in 1885 he went to Emporia College as Professor of Mathematics and remained there fifteen years. While at Emporia he was Acting-President for one year and he served on the Kansas State Board of Education for eight years. Emporia College conferred the Ph.D. degree on him in 1894. He was called to Hanover College in 1900 as Professor of Mathematics. In 1906 he went to Wichita, Kansas, as Principal of Lewis Academy, at that time a flourishing secondary school which the Presbyterians proposed to develop into a college. Later it merged with Emporia College. He returned to Hanover College in 1915 as Professor of Mathematics and before his death in January, 1919, he served two years as Secretary of the Hanover College Board of Trustees. Dr. Lawrence was active in the Presbyterian Church as an Elder, Trustee and Sunday School teacher. An excellent, dedicated teacher of mathematics, he was a Charter Member of the Mathematical Association of America. His wife, Mrs. Arline Lawrence, died in 1956 at the age of ninety-six. They were the parents of two daughters, Mary Abigail (Mrs. J. F. VanAntwerp) and Helen Arline (Mrs. V. C. Taff), both graduates of Hanover College. (Sources: Prof. Ned Guthrie; Mrs. James VanAntwerp, Ottumwa, Iowa; Hanover Alumni Directory.)

JOSEPH MOORE. He was born in Washington County, Indiana, of Quaker parentage, on February 29, 1832, and died on July 9, 1905, in Richmond, Indiana. He spent his early years on his father's farm and received his formal education in Blue River Seminary in southeast Washington County. He began teaching at the age of 18 and taught in district schools in Washington, Jackson and Bartholomew Counties. In the spring of 1853 he entered the Friends Boarding School, now Earlham College. That Fall he began teaching science and continued teaching at the Boarding School for five years. The years 1859-61 were spent at Harvard University where he worked under Agassiz, Wyman, Horsford and Cook, prominent scientists of their day. Earlham College was chartered by the State in 1859 and Joseph Moore returned to Earlham in 1861 as Professor of Geology, Botany and Zoology. He had taught some chemistry in 1858 before going to Harvard. He left Earlham in 1865 because of poor health and went to North Carolina at the invitation of the Baltimore Association of Friends "to advise and assist Friends in the Southern States." For three years he traveled over North Carolina, Virginia and Tennessee, "arousing interest in education, holding normals for the training of teachers, securing money for the building of schoolhouses and, in general, leading the people to rally from the destruction of war and to take up again and more thoroughly the task of training themselves for life." He incidentally made a collection of minerals. In 1868 Haverford College conferred the honorary A.M. on him and he returned to Earlham the

following year as President of the College. He received the LL.D. degree from Indiana University in 1871.

President Moore spent the winter of 1874-75 on a religious and scientific visit to the Hawaiian Islands where he observed scientifically the volcanoes and coral reefs. He shipped home twenty barrels of specimens for the Earlham Museum. He remained at Earlham as President until 1883 when he again suffered from ill health, but during this period he set the policies and standards that have characterized Earlham College. He again went to North Carolina to work with the North Carolina Yearly Meeting in the interest of the New Garden Boarding School and the following year he became its Principal. In 1888 this institution became Guilford College and Dr. Moore was offered the presidency but he preferred to return to Earlham as Professor of Geology and Curator of the Museum.

He was deeply interested in paleontology and during the next twelve years he secured a complete skeleton of the fossil beaver, *Castoroides ohioensis*, until recently the only complete skeleton in existence, and he also prepared a skeleton of the mastodon, both of which are now in the Joseph Moore Museum at Earlham. In 1900, because of his health, he gave up all teaching but continued until his death to be Curator of the Museum.

Joseph Moore was a charter member of the Indiana Academy of Science and he presented thirteen papers, two of them joint papers, to the Academy of which eight were published in the Proceedings. He also published other scientific papers.

"Joseph Moore was a man of singularly winning disposition. Gentle, sincere, sympathetic, he was a true teacher and a genuine, noble man." (Sources: Memorial Number, Earlham College Bulletin, August, 1905; Daughter Lucille H. (Mrs. B. H. Grave), Richmond, Indiana; Earlham catalogues and year books.)

ERASTUS TEST. He was born in Richmond, Indiana, of Quaker parentage, on November 12, 1836, and died after six months of illness, on April 21, 1917, in West Lafayette, Indiana. In his youth he assisted his father in a woolen mill and on the farm. In 1856 he entered Friends Boarding School, now Earlham College. Earlham College received its charter in 1859 and its first two graduates three years later. Erastus Test graduated the next year, 1863, the only one in his class and the first Earlham graduate to receive the B.S. degree. He was Principal of Richmond High School during the year 1864-65 and in the Fall of 1865 he was called to Earlham as Professor of Higher Mathematics to serve during the year's leave of absence of the regular professor, William B. Morgan. In 1866 Professor Test was awarded the first M.S. degree given by Earlham. Because of the disability of Joseph Moore, Professor Test was Professor of Natural Philosophy during the summer of 1866 and then Professor of Chemistry and Botany from 1867 to 1872. However, during this period he took two half-year leaves of absence to attend medical lectures at the University of Michigan where he received the M.D. degree in March, 1868, and later, in 1873, he received the M.D. from Indiana Medical College.

He left Earlham in 1872 to take up the practice of medicine in Dundee, Illinois, and three years later, on account of the health of his family, he

accepted the professorship of chemistry in the Medical Department in Willamette University, Salem, Oregon, for one year, and then, in 1876, returned to Adrian, Michigan, to take charge of Raisin Valley Seminary, an endowed Friends academy, where he remained five years. In 1881 he was invited to establish Central Academy at Plainfield, Indiana, which to his great satisfaction he was able to do in one year, but he remained there one more year. He returned to Richmond in 1883 to teach chemistry and other sciences at Earlham during a year's leave of absence of David W. Dennis, and to assist in the founding of the Richmond Normal School, a private school for the training of teachers directed by Cyrus W. Hodgin. Professor Test gave high school instruction until the Normal School closed in 1886. He then became Principal of Union High School, at Westfield, Indiana, where his work attracted the attention of President Smart of Purdue University who invited him, in 1888, to become Principal of the Preparatory Department at Purdue. When the Preparatory Department was abolished at Purdue in 1894 he was appointed Professor of Mathematics. He retired in 1910 as the first member of the Purdue Faculty to be regularly retired under the provisions of the Carnegie Foundation Retirement Plan. While he was still active the editors of the College Year Book put out a Dr. Test Edition, calling him the "Grand Old Man of Purdue," of which he was tremendously proud.

Professor Test was always interested in alumni affairs. He helped to organize the Earlham Alumni Association in 1877-78 and during the years served as vice-president, member of its Executive Board, and finally president in 1886-87. At Purdue he was active in alumni work and contributed to the support of the Purdue Alumnus.

Dr. Test was a dedicated scientist. He was the father of three sons, Frederick C., who became an M.D., and twin sons, Louis Agassiz and Charles Darwin, both chemists and college professors. Louis was Professor of Chemistry at Purdue for many years. (Sources: The Purdue Alumnus, April, 1917; The Purdue Exponent, June 3, 1910; Mrs. Louis A. Test, Ann Arbor, Michigan; Earlham College Catalogues.)

Biographical sketches have been written for Ryland T. Brown, Oscar L. Kelso, Moses Cobb Stevens, Joseph Tingley, and others, which the author hopes will be published in the Proceedings for 1961.

Progress Made in Increasing Indiana's Human Resources

Stephen S. Visher, Indiana University

A summary of the methods by which the value of Indiana's people has been increased is an interesting and appropriate although unusual subject for discussion before the Academy. Indiana's scientists have contributed significantly to this progress and can assist further by pointing out how the increase in value has been accomplished.

The total value of Indiana's 4½ million people is greater than 45 billion dollars, which is several times greater than the sale value of all of Indiana's land, buildings, roads, railways, parks, minerals, etc. The average value of a person has been calculated in two chief ways—the cost of rearing and educating him, and second, his probable future earnings capitalized, that is how much capital would need to be invested in order to yield the annual income that the person can reasonably be expected to yield.

Recent, careful studies have shown that the average cost of rearing and educating a Hoosier to age 20 now is fully $15,000. However as a fifth of Indiana's present population are small children and a third were reared and educated when costs were considerably less than at present, the average of $10,000 per person is used to obtain the total of 45 billion dollars mentioned.

Influence of Increase in Population

Many influences have combined to create this huge resource. First is the increase in population. Indiana contained fewer than 100,000 people when admitted as a state in 1816. The population increased to 1,000,000 in 1850, to 2,000,000 in 1880, to 3,000,000 in 1920, to 4,000,000 in 1950, and to 4.6 million in 1960. This increase was partly due to immigration from other states and countries but as more people have left Indiana than have come into it since 1850, the major cause of Indiana's increase in population has been the excess of births over deaths. Until about fifty years ago the average birthrate was relatively high and although the death rate was likewise high, it was progressively decreased by varied improvements, including better water supplies, better food, greatly increased medical care, including vaccination, inoculation, "wonder drugs," etc. While a century ago more than half of the children died while young, before they could contribute much, recently healthy infants have excellent prospects of living about 70 years. Thus the average length of serviceable life has been greatly increased.

Influence of Increased Use of Tools and Power

The amount of wealth which the people of Indiana produced in their lifetime has increased greatly. During the earlier decades of Indiana's history most of their work was heavy manual labor, much of it with an ax, as they cut down trees with which to build log cabins, cleared a patch of land for crops, and made crude rail fences. Even saws and plows were rare in Indiana before 1840, and there were few oxen or horses for several decades. In those early years the people of Indiana made their chief contribution to the state's wealth by "hewing homes out of the wilderness" and by rearing children.

Gradually there was an increasing use of tools of ever greater effectiveness, and of power from oxen, horses, and tiny waterfalls in the earlier decades, and later from steam and petroleum. In recent years most Indiana farmers used much equipment—an average of more than $5,000 worth per farm, and a great deal of power, much of it from petroleum but considerable from electricity made with coal. The factory worker formerly had little equipment or power but now has equipment, in most factories, costing several thousand dollars per worker. In many large Indiana factories the equipment used (including the buildings and accessories) costs tens of thousands of dollars per worker, enabling him to produce very much more than an equally able worker could produce only a few years ago.

The Influence of Increased Education

In addition to increase in the number of workers, in their tools and equipment with which they work, and in the amount of help which they obtain from power produced from minerals, the wealth production of Indiana's people has been greatly increased by education.

Increasing the productivity of Indiana's people by improving their education has been accomplished with the help of many people, including parents, neighbors, teachers at each of the levels, clergymen, public officials, newspapers, magazines, and recently by radio and television. Many people not living in Indiana have contributed, people from many foreign lands and of many centuries.

The amount and quality of education in Indiana has increased enormously. While a century ago only a tiny fraction of the people had more than a few months of formal schooling, and there were in the state only a few dozen college graduates, the situation had changed greatly by 1900 when Indiana had hundreds of high schools and more than 50 colleges. Recently a large share of the young adults have graduated from high school and some hundreds of thousands have attended college. In 1960, for example, the various Indiana universities and colleges graduated about 10,000 people, conferring upon several hundred, doctor's degrees, including doctors of medicine, dentistry, education, and "philosophy."

Now people from all of the states and from many foreign countries come to Indiana for part of their advanced education because of the excellence of our offerings. For example, Purdue University, one of the nation's largest engineering schools, attracts many prospective engineers; Indiana University attracts many future physicians, lawyers, and businessmen; Purdue, Indiana University, Notre Dame, the two state teachers colleges and other colleges attract many prospective teachers, as well as people who attend college for other reasons, including the improved opportunities available there to make valuable friendships.

While a century ago, Indiana's schools trained chiefly in reading, writing and arithmetic, now the educational offerings are much more varied. This has been made possible by the expansion of the elementary schools, by a great increase in the number of high schools, and by the enrichment of the offerings. An example as to colleges may be given. Prior to 1890 most college students were preparing to be clergymen or lawyers and much time was spent in the study of Greek, Latin, and the Bible. When the great expansion occurred in elementary and high schools,

a large share of the college students prepared themselves to become teachers. Some forty years ago the rapid growth of cities and industries in Indiana stimulated many college students to prepare for careers in business. Recently only a tiny fraction of Indiana's college graduates become clergymen and less than a fifth become teachers, while roughly a third go into some phase of business.

The educational requirements for success in most fields have risen sharply; for example, in 1900 persons who had not completed high school could teach, practice law, medicine, or engineering. Now college graduation is almost required for new teachers and relatively thorough training is required before lawyers, doctors, dentists, or engineers are permitted to earn a living from their profession.

Increased Work Opportunities

In the early decades of Indiana's history there were only a few ways in which people could make a living. The chief way was by farming. Few clergymen, teachers, or lawyers could earn a living by preaching, teaching, or practicing law, and only a few persons were fully supported by a business.

As no two people are alike in their interests and aptitudes, as the number of work opportunities have increased and the opportunities to prepare for them, the work output of Hoosiers has increased. Now in Indiana there are many thousand different ways of making a living. Even farming has been diversified into more than a score of types each of which appeals to somewhat different types of people. Similarly there are many different teaching positions and thousands of different jobs in the business world.

Increasing the education and work opportunities of Hoosiers has been greatly facilitated by wise counseling. A variety of tests have been developed, especially during the last 50 years, which reveal many of the young person's interests, attitudes, and aptitudes. These tests, being improved year by year by specialists, have in recent years been much used to assist young people. It is highly desirable for each person to discover early what they can do exceptionally well, with pleasure, and to prepare themselves to do it. A major source of satisfaction is doing something well. Conversely, much unhappiness comes from work which is not enjoyed, because it is not done well as a result of lack of interest, aptitude, or training.

The facts that in Indiana there have been increased opportunities for young people to learn what he or she can do well, greatly enriched and extended training (with the help of scholarships and other aid to students), increased leadership, and greater work opportunities have all notably augmented the productivity of our people, and hence their value.

Influences of Increased Use of Natural Resources

In the early decades of Indiana's history, almost no use was made of Indiana's resources other than those of soil, forest, game, and water, and only slight use was made of them. Decades passed before it was learned how to use each of the varied soils to good advantage. Counteracting the excessive acidity, which is normal in forest soils, by the addition of pulverized limestone, and enriching them with appropriate fertilizer has

largely been learned only recently. Reduction of the loss of the precious topsoil by erosion has largely occurred only since the establishment of soi conservation districts in 1937. (Much remains to be done on this line.)

Indiana's wonderful resource of forests unfortunately has been used mostly wastefully. Indeed in obtaining more cropland, many, even choice, trees were burned. Lumbering first was done extensively after railways came in the 1850s. By 1930 few good log trees remained.

Coal, which underlies about an eighth of the state, was first used in considerable amounts shortly after the Civil War. Petroleum and natural gas began to be used shortly before 1890. Indiana's choice building limestone was little used until the 1890s, and little gravel and crushed limestone were used before 1900. The large amount of land which was often too wet was considered to have almost no value for decades. The laborious draining of parts of the wetland commenced in the 1870s. Much of about one-eighth of the state which formerly was "wetland" has recently become almost the best farm land in the state and some of the best in the nation.

Indiana's water resources greatly increased in value as the population grew. The lakes of northern Indiana had very little value prior to about 1910, but now are so valuable that it is illegal to drain a natural lake. Many artificial lakes and ponds have been created. Lake Michigan's value to Indiana greatly increased when the steel mills of Gary were established in 1906. Indiana's underground water resource, exceptionally bountiful in most places, was slightly used for decades, but recently has been highly valuable.

Indiana's total productivity was increased also as additional minerals were discovered and used. An example is clay suitable for the making of brick and tile and "fire clay," which is used for the making of special tile and heat-resisting brick. Another example is the use of stone especially suitable for making cement and another stone useful for the manufacture of "rock wool" used for insulation. A hard limestone especially suited for making crushed rock for roads and concrete has become in recent years highly valuable. The pulverized limestone by-product of crushing has been extensively used to sweeten the soil and increase crop yields and grass growth. The latest great mineral resource to be discovered and used in Indiana is gypsum, recently extensively mined near Shoals, Indiana.

Each of these increased uses of natural resources also increased work-opportunities for people and hence the value of the human resource.

Influences of Introductions

The productivity of the people of Indiana has been greatly increased by the introduction into the state of new plants, animals, and people. None of the crops now important in Indiana are native here. The chief crops, hybrid corn, soybeans, wheat, oats, and tomatoes, and grasses and legumes used for pasture and hay were introduced mostly from Europe and Asia. However, hybrid corn and the varieties of wheat, oats, and soybeans now grown were developed in the U. S. from forms which had been introduced. The same is true of the fruits, melons, potatoes, and nearly all other crops grown.

Similarly the several kinds of domestic animals now important in Indiana were introduced mostly from Europe. Varieties of these have

been developed in the U. S. but none in Indiana. However, Purdue scientists made a notable contribution in increasing egg production by hens.

Although, as already remarked, more people have left Indiana than came into the state, the contributions of some of those who entered the state were very important. For example the Quakers and Scotch Presbyterians who came from the South during pre-Civil War years proved highly valuable educationally, as did some of those from New England or of Yankee ancestry from New York and Ohio. Some of those who came direct from Europe, notably Germany, contributed greatly too. Indeed a sizable percentage of the present huge value of Indiana's human resource reflects the influence of immigrants.

Summary and Conclusions

Indiana's human resources, now having a total value in excess of 45 billion dollars, a sum greater than the value of all Indiana's material resources, have grown in value as a result of many influences. A listing of some of these, here done, augments our appreciation of them. Progress is continuing, but much remains to be done, especially in reducing deaths from accidents, in making better use of women, of elderly people, and of handicapped people, and by increasing the usefulness of persons who possess more than average ability. All members of the Indiana Academy of Science can assist in some aspects of this worthy project.

The Academy from Horse and Buggy to Jet

Fay Kenoyer Daily, Butler University

In December, 1960, the Indiana Academy of Science will be seventy-five years old. This affords a splendid opportunity to express my appreciation for the opportunities of fellowship and stimulation in scientific endeavors available to me through membership in this organization, and to review, briefly, the aims, activities and some expressed plans for the future, hoping that in so doing, greater participation in our programs may be stimulated and aid may be recruited in solving the problems at hand. For the fulfillment of aims becomes increasingly difficult in a changing world, and even more important.

The establishment of our society was largely due to the effort of Amos W. Butler who developed a great ability for organization and persuasion of men as evidenced by the great number of organizations in which he had a part in founding and supporting (11). A group of naturalists had organized the Brookville Society of Natural History in 1881 with Butler's aid, and lectures, many of which were on scientific subjects, had been arranged for them by the Rev. David R. Moore. Also in 1881, Butler attended the American Association for the Advancement of Science meeting at Cincinnati, Ohio, which was especially significant for us as described in his own words (2): "This was the beginning of many acquaintances that have been permanent, helpful and inspiring. In my efforts to study local natural history, I found it difficult to obtain information from students in other parts of the state. In talking with others, I found they had had the same difficulty. In the winter of 1883-1884, the need of a State organization was strongly impressed on me. Correspondence was begun with a number of persons whose names were prominent in scientific work of the State, and the majority of them favored such an organization."

Again at an A. A. A. S. meeting in 1884, the matter was discussed and it was decided to call a meeting to organize an Indiana society in which the Brookville Society of Natural History was asked to take the initiative. That society appointed an organizational committee consisting of Rev. David R. Moore, president, Dr. S. P. Stoddard and Amos Butler. With the enthusiastic support of David Starr Jordan, J. P. D. John, John M. Coulter, Stanley Coulter, Philip S. Baker, Daniel Kirkwood, Richard Owen, Oliver P. Jenkins, John C. Branner and others, a meeting was called for Indianapolis, December 29, 1885, and the Indiana Academy of Science was born. About forty people attended this first meeting. Papers were presented dealing primarily with natural and physical science studies of the state of which a bibliography was assembled. Plans were made to publish these.

In the constitution (8), the following objects were written: "The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science." Active members were defined as, "Any person engaged in any department of scientific work or original research in any department of science . . ."

The enthusiasm with which Academy meetings were hailed seems remarkable especially when one considers the conditions of travel and

communications then. At the time of the first meeting in Indianapolis, public transportation was by horse car, the electric railway not appearing until 1890. However the steam railway was well established over the state. To the west, there was still a rough, noisy frontier with menacing bands of Indians. Few telephones were in Indianapolis in 1885, having been introduced in 1877. Practical radio came in 1895.

The holding of field meetings of the Academy began in May, 1886, at Brookville, Indiana, with an evening meeting the preceding day, and they have continued through the years with little interruption. The annals of the 1888 spring meeting were, in the words of Amos Butler, "classic to Indiana scientists." About thirty-three members drove by carriage from Paoli to Wyandotte Cave in Crawford County. They were lost and drove about forty miles to get there. Amos Butler broke out with chickenpox on the way. Since it was past the meal hour when they arrived, they had to take what food was available. Also after they arrived, they were told that they could see the cave as well by night as by day, so spent the evening and early part of the night exploring the cave. The group returned to Paoli the next day by way of Marengo Cave (3).

The chronicles of the early fall meetings show interest in several projects by the titles of committees to handle them: Biological Survey, Cooperation of Educational Societies, Plan for Publication, State Library, Incorporation, Legislation for Destruction and Restriction of Weeds, Legislation for Protection of Native Birds, Dividing the Academy into Sections, Preservation of Aboriginal Earthworks near Anderson and Relations of the Academy to State.

It was 1892 when the first issue of the *Proceedings of the Indiana Academy of Science* appeared covering the 1885-1891 meetings. This was made possible by contributions from individuals and business firms to bolster Academy funds to defray expenses. However, not all papers presented during this time could be printed in full and many were reported only by title and some manuscripts were misplaced. Therefore, it became apparent that state aid should be sought to make this a useful publication in which scientific articles of educational, industrial and economic interest to the state could be collected rather than be scattered in other journals or lost. A plea was made before the Indiana General Assembly, 1895, in which the work and purposes of the Academy were outlined (9), and an act to provide for publication of reports and papers of the Indiana Academy of Science was approved March 11, 1895 (10). It is a tribute to our past editors and contributors as well as the fine support of the state that this journal has been held in high esteem through the years. Its many papers are a wealth of information about subjects of particular interest to the state. Each member of the Academy and Indiana libraries receive a copy of the Proceedings, but in addition, volumes are sent out to libraries all over the world on an exchange basis. By this program and by special grants to buy missing volumes, a large scientific library has been accumulated. Demarchus Brown, State Librarian, in 1907 made an agreement with the Academy to catalog and shelve the documents and reports belonging to it, making this material subject to removal by any member of the Academy and subject to reference by the public. The John Shepard Wright

Memorial Library at the Indiana State Library Building houses this valuable collection (Coats, 4).

From 1885 to 1909 when the Indiana Academy of Science celebrated its twenty-fifth annual fall meeting, there was rapid growth of communication and transportation. The automobile was a noisy newcomer to the changing scene, the first automobile trip across the nation from San Francisco to New York occurring in 1903 and the first heavier than air mechanically propelled airplane flight by Orville Wright being made the same year. There had been a significant growth in industry and population. In the speeches given at the twenty-fifth anniversary meeting of the Academy in 1909, there were repeated reports of the revolutionary changes in science during the previous twenty-five years. Greetings and congratulations were extended to the society from Indiana State Teachers Association, Indiana Medical Association, Indiana Historical Society, Indiana Branch of the American Chemical Society, State Physics Teachers Association, Indiana Society of Engineers, Indiana Association of Science and Mathematics Teachers and the Indiana Audubon Society. Papers were presented at the following Sections of the Academy: General, Chemistry, Mathematics, Physics, Geology and Geography, Zoology and Botany. In addition to committees appointed to carry out regular Academy business, a committee on Weeds and Diseases as well as one on Biological Survey and one for the Protection of Native Birds had been established.

J. S. Wright, a great benefactor of our society, expressed some plans for the future at that meeting which seem pertinent today (12). It was urged that action be taken to meet the following needs: to welcome more scientists from state industry and to accent the social side of our society to promote an atmosphere favoring greater exchange of ideas. Other members emphasized these plans and expressed other needs.

In 1919 (1), a committee consisting of R. W. McBride, J. S. Wright and H. L. Bruner presented a plan which was adopted to establish and administer the Academy Foundation Fund for the promotion of research by responsible members of the Academy. The funds were to be obtained by setting aside an amount deemed appropriate by the treasurer from the Academy revenue each year, from life membership fees, money from patrons, gifts etc. Annual proceeds of the fund were to be reinvested to become a part of the principal fund until the principal was sufficient to yield an annuity of two hundred dollars. This has reached maturity in recent years and is used along with A.A.A.S. funds provided for grants to aid in research. The Research Grants Committee of the Indiana Academy of Science considers applications for grants and recommends the projects to be supported by these funds. This program has made possible important scientific work that might not have been done if these funds were not available.

The Junior Academy of Science, an important adjunct of the senior Academy, began in 1931. H. E. Enders, chairman of a committee comprised of S. R. Esten, Frank B. Wade, O. B. Christy and L. J. Rettger, reported on plans to establish this society and proposed an amendment of our constitution to accomplish this act (6). This was adopted. A meeting was held for interested clubs and regulations for affiliation of high school science clubs with the Indiana Academy of Science were adopted (7). A

constitution for the Junior Academy of Science, as this affiliation was to be known, was modeled after that of the senior Academy. Sidney Esten was appointed "field" and "contact" man for the Junior Academy of Science. Dr. Enders served as Chairman for this group until 1946. Dr. H. H. Michaud served as co-chairman that year and has been chairman ever since. The papers and exhibits presented at these meetings have been of great merit. Cash awards have been provided by gifts, and a National Science Foundation grant has provided a visiting teachers program for high schools.

Turning to world conditions from 1909 when the Academy celebrated its twenty-fifth annual fall meeting to 1934, the fiftieth fall meeting, we see that these years marked some very troubled times. Increasing tensions resulted in the first world war entered by the United States in 1917 and in which we were involved until the armistice was signed on Nov. 11, 1918. In 1927, Charles Lindbergh made the first non-stop flight from New York to Paris in his monoplane. In 1929, the stock market crash marked the beginning of a severe depression, the results of which were still evident at the end of this twenty-five year period. The impetus to scientific advance, however, stimulated by the recognition of the contribution of science to winning the war was quite significant.

When the fiftieth fall meeting of the Indiana Academy of Science was held in Indianapolis at Butler University in 1934, an address was given by Will E. Edington (5), *There were giants in those days,* which outlined early scientific influences in the state and included biographical sketches of some outstanding charter members of the Academy. Fifteen living charter members, ten of whom attended the meeting, were honored. Papers were presented in the general session as well as in the following Academy Sections: Botany, Chemistry and Bacteriology, Geology and Geography, Physics and Mathematics, and Zoology. Other committees in addition to those appointed for handling the regular Academy business of holding meetings and publishing the Proceedings were Archeological Survey, Library, Research, Academy representative to the A.A.A.S. Council, Biological Survey, the Relation of the Academy to State, and Junior Academy of Science.

Soon after our fiftienth anniversary, the United States was again plunged into war when we entered World War II in December, 1941. Television was introduced that year, but was used chiefly for military purposes until after the war. The first nuclear chain reaction was produced in 1942 leading to the production of the atomic bomb. When the first atomic bomb used in war was exploded on Hiroshima, it resulted in an early end to the war in May, 1945. A charter was adopted by the United Nations Conference in 1945 with the United States of America joining the association. As a police action desired by the United Nations, the United States intervened in the Korean War 1950-1953. Again scientists aided substantially the national effort in these two wars, with the result that a greater understanding and stimulation of scientific endeavor developed. Also, after World War II, an ideological or "cold war" brought scientific achievement into the struggle for prestige among nations so that now programs for scientific research and education are burgeoning in great profusion. The population explosion adds greater problems in education.

The first jet liner passenger service was started in 1952 and the first passenger service across the Atlantic by jet began 1958. The space program, begun with Sputnik I, 1957, has provided valuable scientific information with the use of earth satellites, artficial planets and moon rockets. We seem to be on the threshold of sending man into space.

In the Academy during the twenty-five year period from 1934 to 1959, the *Indiana Plant Distribution Records* were started to supplement Deam's *Flora of Indiana* with current reports. Several Academy publications of note were *Indiana Scientists*, 1951, by S. S. Visher, a fifty year index for the Proceedings begun by G. H. Smith and finished by R. C. Friesner as well as a ten year cumulative index by R. C. Friesner, 1948 and 1952, respectively. Special interests were expressed in having an Indiana State Museum and in Conservancy of Natural Areas.

In 1959 when the Academy held its seventy-fifth annual fall meeting, several committees were devoted to duties other than the regular business of the Academy: Biological Survey, Index, Indiana Talent Search, Junior Academy of Science, Library, Relation of Academy to State, Represenative on the Council of A.A.A.S., Science Education, and Indiana School and College Committee on Mathematics.

Papers were given before the General Session and the Divisions of: Anthropology, Bacteriology, Botany, Chemistry, Entomology, Geology, and Geography, History of Science, Mathematics, Physics, Plant Taxonomy, Psychology, Soil Science and Zoology. These divisional meetings, where the research of members is presented in short, concise accounts, continue to stimulate and encourage members to pursue and present research of great value to the state of Indiana. Members of the Academy come from many occupations. Many teach in state and private colleges and universities, but there are also public and private school teachers from high school and grade school levels. College students are encouraged to attend by offering a reduced charge for membership to them. Professionally retired members add another important group to the membership. Research personnel come to the Academy from federal, state and local offices. Other members come from the fields of engineering, pharmacy, natural history museums, medicine, library, religion, real estate sales, law and others. All of these people have a common bond in the pursuit and reporting of scientific research at our meetings.

The spring meetings of the Academy have continued through the years with little interruption as a special time for Indiana scientists. In addition to the business meeting, hikes and collecting trips arranged for, there is time for members to become better acquainted and exchange ideas in the informal atmosphere provided. We do not have today the physical hardships of travel experienced by those zealous members who drove by horse and buggy from Paoli to Wyandotte Cave, May, 1888; but with public travel by jet from coast to coast in the United States in four hours now, we would probably not even have the patience for that long, difficult trip of yesteryear. The pace was laboriously slow then with difficulties in communication and transportation due to lack of effective instruments and vehicles. Today the pace is swift. There are astonishing instruments of communication and vehicles for transportation, the difficulty is finding time to use them. Greater complexities of civilization

demand more of the scientist's time, and he is active in an ever increasing number of societies. Thus, there is a much greater chance of information vital to the state to be scattered. Therefore, our Academy plays an increasing role in stimulation of research and science education in the state, and in assembling and communicating information of vital interest to the welfare of Indiana. We must exert every effort to keep the Indiana Academy of Science strong.

Literature Cited

1. Bruner, H. L., R. W. McBride, and J. S. Wright. 1921. Revised report of the committee—a plan for the establishment and administration of a fund for the promotion of research. Proc. I. A. S. for 1919, pp. 41-44.
2. Butler, Amos W. 1910. The beginning of the Indiana Academy of Science. Proc. I. A. S. for 1909, pp. 35-37.
3. ————————. 1924. Early history of the Indiana Academy of Science. Proc. I. A. S. 33 : 14-18.
4. Coats, Nellie M. 1954. The Academy's John Shepard Wright Memorial Library. Proc. I. A. S. 63 : 248-252.
5. Edington, W. E. 1935. There were giants in those days. Proc. I. A. S. 44 : 22-38.
6. Friesner, R. C. 1932. Minutes of the Indiana Academy of Science. Junior Academy of Science Committe Report by Chairman, H. E. Enders. Proc. I. A. S. 41 : 25.
7. ————————. 1932. Minutes of the Junior Academy of Science. Proc. I. A. S. 41 : 27-28.
8. Indiana Academy of Science. 1894. Constitution. Proc. I. A. S. for 1893, pp. 7-8.
9. ————————. 1896. Work and purposes. Proc. I. A. S. for 1895, pp. 7-11.
10. Indiana Laws, Statutes, etc. 1896. Act to provide for the publication of the reports and papers of the Indiana Academy of Science. Proc. I. A. S. for 1895, pp. 4-5.
11. Lyon, Marcus Ward, Jr. 1938. Necrology—Amos William Butler. Proc. I. A. S. 47 : 21-25.
12. Wright, J. S. 1910. Plans for the Indiana Academy of Science. Proc. I. A. S. for 1909. p. 48.

MATHEMATICS

Chairman: KERMITT H. CARLSON, Valparaiso University

MERRELL E. SHANKS, Purdue University, was elected chairman for 1961

ABSTRACTS

Mathematics and the Younger Generation. HANS J. ZASSENHAUS, University of Notre Dame.—Teaching techniques are suggested which will enable the teacher to maintain his own standards of performance while allowing the student freedom in pursuing his own goals which include passing examinations, acquiring knowledge, learning how to learn, getting a degree, discovering himself and developing a fitness to serve the community. Emphasis is on freedom of self-expression for the student and acknowledging that each student is unique and must be treated accordingly. The axiomatic method, especially, does not really work except with perhaps ⅓ of all students. Mathematics is more than just a set of rules. It is not merely a formal system. It makes itself felt by confronting us with reasonable problems. We succeed with the student insofar as we arouse his interest in these problems.

The Mathematics Program at Rose Polytechnic Institute. T. P. PALMER, Rose Polytechnic Institute.—All students at Rose are required to take 18 hours of mathematics through differential equations. The freshman year is the same for all. A mathematics major in his sophomore year may take modern geometry and matrix theory in a 3 hour elective spot. In his junior year he takes 6 hours of advanced calculus, 6 hours of vector analysis and theory of functions of a complex variable along with modern physics, a language, a technical elective and a course in the humanities. In the 1st semester of his senior year he takes advanced differential equations, statistics, modern algebra, engineering analysis, a technical elective and a humanities elective, while in the 2nd semester he takes numerical analysis, hydrodynamics, mathematics seminar, two technical electives and a humanities elective. The total program consists of 51 hours of mathematics, including 33 hours beyond the required differential equations. The mathematics seminar is of unspecified content. Topics which have attracted interested students are stability theory, probability theory, topology and finite dimensional vector spaces. One non-required course offered by the department is Mathematical Methods for Digital Computers, which centers around the Bendix G 15d computer now installed at the Institute.

Crises Past and Present (invited hour address). R. CREIGHTON BUCK, University of Wisconsin, Chairman of the Committee for the Undergraduate Program in Mathematics.—A review of the development of mathematics in the U. S. from 1900 and a prospectus for future growth based upon recommendations of the Committee for the Undergraduate Program, with special emphasis on the activity of the Panel on Pre-graduate Training. Of first importance to the student of mathematics is that he develop his ability to read and enjoy the appropriate literature. Mathe-

matics is full of idiom which he must learn to interpret. He must become aware of the traditions and history of mathematics. Too many textbooks today seem to have been written by machines, there is so little humanism in them. Furthermore, our emphasis on rigor has served only to remove the excitement from mathematics. Techniques are important. The methodology of proof is learned best through the experience of reading proofs. It is also important that the student develop the proper attitude of looking beyond his immediate objective; too many stop developing with the Ph.D. Finally, there is the question of whether teaching must always be right the first time. Do we prove everything, or must some things be unlearned? The fact is that mathematics develops from hazy ideas and unformed conjectures, and the "Satz-Beweis" tradition must yield to a tolerance for laxity. There are actually fewer Ph.D.'s teaching mathematics in the U. S. than there were 10 years ago. What is required to meet the increased demand is not known, but a relaxation of the requirement of a Ph.D. seems called for. The Committee for the Undergraduate Program recommends a Doctor of Arts degree in which the thesis is expository or critical.

The State of Mathematics in the State of California. HARLEY FLANDERS, Purdue University.—The phenomenal growth of California marks it as special. In 7 years it will be the largest state. In 1959 the University of California at Berkeley had 19,000 students and a permanent mathematics staff of 45. Enrollment for 1965 is estimated at 26,000-35,000, mathematics staff a very conservative 80, possibly 100. A major factor in the growth of mathematics there is the opportunities for mathematicians in industry and government. The state college system is coming into competition with the university system by offering Ph.D.'s. There is a danger that the state college system will adopt the Doctor of Arts degree and distort it to something not intended by its originators. The training of secondary teachers is done in the state college system. Another unique feature of California is its system of 40 junior colleges. In the future these will carry the sole responsibility for offering the first two college years. There are no small schools among California's 300 high schools. Once a California teacher has a secondary credential he may teach any subject. Twenty-five per cent of California's high school math teachers had no math in college. The credential situation is currently under review.

Comments on the Liaison Between High School and College Mathematicians. ARTHUR E. HALLERBERG, Valparaiso University.—The problem of articulation between school and college mathematics will almost certainly become more complicated before generally accepted procedures evolve. Furthermore it will not be solved by committee reports, by particular superior experimental programs, by the general adoption of a single pattern of high school mathematics courses or by adoption of a uniform set of college admission requirements. Rather, some satisfactory state of affairs in the transition will be obtained only after full and free conversation and interaction between secondary school and college teachers and between the teachers of mathematics at all levels and those who are doing, inventing and applying math. The changes, when they come, must come at all levels of teaching. Factors contributing to the problem, but which may also contribute to its solution, are: (1) the watertight com-

partments of mathematics have been broken, (2) the lines of demarcation between junior high school, high school and college math are being erased, (3) modern mathematics is making an impact on the curriculum, (4) physicists, chemists and engineers still want traditional mathematics, notably the calculus, as early as possible. Suggested action: Teachers and administrators should become informed of recent actions of the National Council's Secondary School Committee and of CUPM. We should work through some of the new materials such as those of SMSG or Ball State. Read about new proposals in "Math Teacher," "School Science Math" and "Math Monthly." Encourage institute participation and local participation in activities of ISCCM, Continental Classroom, etc. Experiment with new ideas even in traditional classes. Finally, communicate through periodicals and meetings.

Interdepartmental Seminar: A New Mathematics Course at DePauw. ROBERT J. THOMAS, DePauw University.—Interdepartmental Seminar was introduced at DePauw in 1958. It is a small class for senior students in chemistry, mathematics or physics which treats mathematical topics from any of the three fields. The student's work is largely independent study.

PHYSICS

Chairman: C. S. Morris, Manchester College

Howard Black, Indiana State Teachers College, was elected chairman for 1961

ABSTRACTS

A Project in Gamma Ray Spectroscopy. Charles S. Morris and Roger Dilling, Manchester College.—The gamma ray spectrometer, consisting of two single channel spectrometers with a coincidence circuit, in use in the Manchester College physics department, is described. Spectra of Cs134 taken with this apparatus are shown and discussed. The necessity of collimation is indicated by contrasting a collimated with an uncollimated spectrum. The contribution of coincidence data to the determination of decay schemes is discussed and illustrations given. Further proposed work on Cs134 is described.

Direct Interactions in (∝, p) Processes.[1] W. D. Ploughe, Purdue University.—The direct interaction which is most probable in the case of (∝, p) reactions is the knock-out process. In this process the incident alpha particle interacts directly with a single proton of the target nucleus, and the proton is ejected while the alpha particle is captured into the residual nucleus. A "crude" theoretical treatment of such a process predicts that the angular distribution of the outgoing protons should be given by the square of a sperical Bessel function in which the argument is angle dependent. A comparison of this "crude" theory with the (∝, p) reactions on fluorine, sodium, aluminum, and silicon will be presented.

The Status of Physics Teaching and Research in Indonesia. Lewis W. Salter, Wabash College.—The writer, recently returned from two years residence in Indonesia as a visiting faculty member at the Institute of Technology in Bandung, summarizes briefly some of the problems and progress in physics teaching and research in present day Indonesia. Special reference is made to the problems in laboratory teaching resulting from deep rooted cultural differences between east and west, and to the beginning of a modest nuclear training and research program based on a Triga type reactor presently under construction.

An Extension of Maxwell's Demon Theory. John G. Gosselink, Hartford City.—The adiabatic lapse rate law is rigidly derived, not as commonly supposed as holding only for a state of convective equilibrium, but for static equilibrium as well. This raises the question of whether introducing the factor of "bias" into the mathematical principle of statistical probability by the spontaneous action of the gravitational field, the result Maxwell postulated that his demons could bring about in the submicroscopic realm may be brought into the macroscopic realm.

1. Supported in part by the U. S. Atomic Energy Commission.

Teaching Physics with an Analog Computer. D. L. SHIRER, Valparaiso University.—Differential equations are the heart of physics, but students often do not grasp the essential physical structure of a problem because of difficulties with the mathematical solution of the equations. Numerical, digital and analog methods of solution of complicated equations, if treated properly, do not obscure the basic physics of the situation. The use of a small analog computer to solve differential equations as a lecture aid and an advanced laboratory tool is discussed. Typical problems in mechanics, heat, nuclear and reactor physics are illustrated, and suggestions are made as to its optimum use in the classroom.

Proton Magnetic Resonance Spectra of Amino Acids in D_2O Solution. L. DWIGHT FARRINGER, Manchester College.—Application of nuclear magnetic resonance to the study of molecular structure is discussed, with particular reference to the proton resonances of D_2O solutions of some amino acids. Chemical shifts due to diamagnetic shielding are described and correlated with known molecular structures. Splitting of resonances due to spin-spin coupling between proton groups at non-equivalent sites is also described. Concentration dependence of some of the chemical shifts, notably those of the proton resonances of the amino groups, are described and interpreted in terms of a rapid exchange of protons between the hydrogen sites of these groups and of the solvent molecules.

The Interaction of an Electromagnetic Field with a Finite Plasma. J. G. WOLFE, Indiana State Teachers College.—The interaction of a plane electromagnetic wave with a parallelepiped-shaped neutral plasma of length L and sides a, b such as might be produced by a hypersonic missile in the earth's atmosphere is considered. It is assumed that the positive and negative particle densities are zero outside of the plasma which would be approximately true for the plasma wake of a missile in the lower atmosphere. As the plane wave enters the plasma, charge separation occurs and a pure electric field is produced in opposition to the driving field. The differential equation for this internal field is derived from Maxwell's equations and the solution is obtained. With this information the radiation field of the excited plasma and the reflection coefficient is calculated.

Half-Lives of Some Nuclear Energy States in the mμ-Sec Region.[1] T. D. NAINAN, Indiana University.—By using a fast time-to-pulse height converter in conjunction with a 100 channel analyzer, the life-times of several short-lived nuclear states have been measured. The apparatus uses a single channel pulse height analyzer in each branch. The results fall into two classes: (a) Half-lives on which there is disagreement between several investigators or which have only been measured by other techniques. (b) New results. Under class (a) the values are as follows:

124 kev state of Cs^{131} $4.10 \pm 0.05 \times 10^{-9}$ sec;
323 kev level of V^{51} $0.29 \pm 0.04 \times 10^{-9}$ sec;
123 kev level of Gd^{121} $1.15 \pm 0.07 \times 10^{-9}$ sec.

---

1. Supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

(b) New results: 555 kev level of Mn^{52} $1.85 \pm 0.05 \times 10^{-9}$; 155 kev level of Sb^{119} (from Te^{119}) $0.84 \pm 0.05 \times 10^{-9}$ sec.

246 kev level in Se^{77} $1.30 \pm 0.08 \times 10^{-9}$ sec;
1490 kev level in Co^{57} $1.0 \pm 0.05 \times 10^{-9}$ sec.

An Artist's Response to the Land Color Theory. JAMES R. ADAMS, Manchester College.—Color as a sensation is discussed in relation to the Land experiments in color vision. Simple ocular experiments are described whereby implications of the Land experiments can be verified without special equipment. It is suggested that the scientist re-evaluate the color experience of the artist.

Proton Polarization Measurements. WILLIAM P. JOHNSON[1], Indiana University.—Counters and electronics have been developed to measure the polarization of protons produced in various types of nuclear reactions. This proton polarimeter is placed at the focus of a heavy-particle magnetic spectrometer. Proton groups corresponding to nearby states in the residual nuclei under investigation can be resolved and their polarizations measured. Measurements of the polarization of protons produced in elastic scattering of alpha particles from hydrogen will be reported. Preliminary studies of the polarization of protons produced in (d,p) reactions on several targets will also be described.

Satellite Telescopes and Meteorites. PAUL E. STANLEY, Purdue University.—Since the earth's atmosphere is at best only semi-translucent to a large portion of the electromagnetic spectrum, considerable interest is evidenced in the possibility of orbiting astronomical observatories operating far above the atmosphere. Numerous obstacles to such an operation exist, not the least of which is possible damage to the reflecting surface by meteorites impacting upon it. An analysis of the best data on the nature of meteorites and their flux in the vicinity of the earth as well as the phenomena associated with high velocity impact indicates that the damage is very dependent upon the size of the smallest meteorite particles. If no particles smaller than 10^{-11} grams exist, little damage is anticipated in less than several months.

Shape of Beta Spectra of Once Forbidden Transitions in the Decays of Ga^{72}, La^{140}, Eu^{152}, Eu^{154}, and Sb^{124}.[1] D. R. SMITH and L. M. LANGER, Indiana University.—Magnetic spectrometer studies were made on the beta spectra of Ga^{72}, La^{140}, Eu^{152}, Eu^{154}, and Sb^{124}. The highest energy beta group of each of these transitions has an abnormally long comparative half-life and probably is a once forbidden decay from a 3— initial state to a 2+ final state. For all, the highest energy beta spectrum was found to have a nonstatistical, nonunique shape. On the assumption that the B_{ij} matrix element dominates the decay, the experimental shape factors were fitted empirically by $C = q^2 + \lambda p^2 + D$. The best fits were obtained for values of D equal to 15, 10, 5, 20 and 15 for Ga^{72}, La^{140}, Eu^{152}, Eu^{154}, and Sb^{124}, respectively.

---

1. Supported by the Office of Naval Research and the U. S. Atomic Energy Commission.

Student Experiments in Neutron Physics. M. M. BRETSCHER, Valparaiso University.—Since 1958 Valparaiso University has operated a subcritical nuclear training reactor made possible by assistance from the Atomic Energy Commission. Experiments now performed in the reactor physics laboratory include: albedo determinations of water and paraffin for thermal neutrons, angular distribution of thermal neutrons diffusing from a paraffin surface, thermal neutron diffusion length measurements, age to indium resonance for Pu-Be neutrons in water, absolute thermal flux measurements by beta-gamma coincidence method in gold, mean lifetime of thermal neutrons in water, determination of neutron resonance energies, the exponential experiment, neutron scattering and absorption cross sections, neutron temperature measurements, neutron source calibration. A unique method for determining the diffusion length of thermal neutrons in light water using a Pu-Be neutron source has been developed. Axial and radial flux distributions are measured with a small BF_3 probe in a water moderator having cylindrical geometry with the neutron source located on the axis of the system at its base. The effect of the source term, arising from the slowing down of fast neutrons into the thermal group, in the one velocity diffusion equation is eliminated by a cadmium difference technique. The Fourier-Bessel coefficients in the series expansion of the thermal neutron flux are experimentally determined, thereby making it possible to correct the results for the harmonic effect. In this manner the diffusion length of thermal neutrons in light water was measured and found to be 2.84 ± 0.11 cm. Values quoted in the recent literature vary from 2.67 to 2.88 cm.

PLANT TAXONOMY

Chairman: W. A. Daily, Eli Lilly and Company

Mrs. Helene Starcs, Health and Hospital Corporation of Marion County, was elected chairman for 1961

ABSTRACTS

The Role of Paper Chromatography in Taxonomy. C. W. Hagen, Jr., Indiana University, Bloomington.—Paper chromatography will become an important adjunct to the taxonomist's armamentarium because it offers a means of examining far more attributes from a single specimen than can conveniently be assessed by any other method. It also offers possibilities for determining degree of relationship and even direction of evolution among closely related taxa. The obvious advantages of the technique may lead to serious errors, however, if the attributes revealed on chromatograms are not subjected to the same rigid evaluation as morphological and cytological characteristics. Erroneous conclusions may arise from failure to assess variation within taxa, failure to establish identity of compounds derived from different taxa, and attempts to relate degree of pattern differences on chromatograms with degree of relationship. Most of these difficulties can be obviated by the realization that the attributes under consideration are chemical compounds, not spots or patterns of spots on chromatograms.

A Wide Species Cross in the Genus *Solanum* (*S. integrifolium* Poir. X *S. melongena* L.). Willard Yates, Cumberland College, Kentucky.—In reciprocal crosses of the eggplant, *Solanum melongena* and the ornamental *S. integrifolium* hybrids were secured only with the latter species as the female parent. The hybrids showed conspicuous heterosis but were completely male sterile and showed highly reduced seed set, although it was possible to obtain backcrosses to both parents. Treatment of the F_1 hybrids with colchicine led to the production of an allotetraploid which showed 25-33% pollen fertility but the seed set still remained low. Pollen viability percentages determined by staining with cotton-blue were checked by germination of pollen on nutrient agar, and a high degree of correlation was obtained. At meiosis in the F_1 chromosome pairing was essentially regular and this fact coupled with the reduced fertility of the allotetraploid would suggest that the sterility is genic rather than chromosomal. The taxonomic position of both *S. melongena* and *S. integrifolium* is in great need of clarification. The proper name for the species here identified as *S. integrifolium*, in fact, is far from certain, and it is possible that it should be referred to *S. aethiopicum* L. and that *S. ovigerum* Dun. is a synonym. Until type specimens are examined, the correct name will remain in doubt.

Taxonomic Problems in *Lespedeza*. Andre F. Clewell, Indiana University.—The difficulty in keying native Lespedezas and the occurrence of occasional extraordinary specimens in most stands of the species has led to an intensive study of populations near Bloomington. Data obtained

during the past two years indicate that variation arises primarily from two sources: one is ecological due to sun and shade forms of each species; the second is due to interspecific hybridization. Transplant studies have provided the ecological data, while most of the evidence for hybridization has come from analyses of mass collections from sympatric populations of *Lespedeza hirta* and *L. intermedia.* In such stands a third taxon, *L. Nuttallii,* occurs infrequently, and when scatter diagram techniques are applied to such populations, *L. Nuttallii* appears as a morphological intermediate between the first two species. Artificial crosses between *L. intermedia* and *L. hirta* are underway; and plants grown from seed taken from wild specimens of *L. Nuttallii* show variation towards the suspected parental species. All species have a chromosome count of $n = 10$, and *L. Nuttallii* shows a number of univalents at meiosis, indicating imperfect pairing. Field studies in seven states show that taxonomic problems in other species probably also can be attributed to both ecological modification and interspecific hybridization.

A New Annual Sunflower, *Helianthus deserticolus*, from the Southwestern United States

Charles B. Heiser, Jr.[1], Indiana University

Helianthus deserticolus, Heiser *sp. nov.*

Herba annua, 1.0 - 4.0 dm. alta, caule virido vel rubro, ramoso, dense hispido; laminis lanceolato-ovatis, hispido-hirsutis, integris, 2.5 - 5.0 cm. longis, 1.0 - 2.0 cm. latis; disco 1.3 - 2.5 cm. diam.; phyllariis linearilanceolatis, brevo-acuminatis, hirsutis, discum superantibus, plerumque 1.4 cm. longis, .2 cm. latis; radiis ca. 10, 1.0 - 2.0 cm. longis; paleis receptaculi ad apicem hirsutis vel raro glabris; acheniis 4 - 5 mm. longis, pilosis, pilis 0.5 - 1.0 mm. longis; pappi paleis 2, ca. 2.5 mm. longis, et squamellis ca. 10, 0.5 - 1.0 mm. longis.

Southwestern Utah, northwestern Arizona and Nevada. Chromosome number: n = 17 *(Heiser 4518) (Stoutamire 2574)*. May to October, 2100 to 4500 ft.

Specimens seen:

Utah: Washington Co., 3.3 mi. w. of Hurricane, June 29, 1957, *Warren P. Stoutamire 2574* (IND. TYPE); LaVerkin, *M. E. Jones 5183m* (US); Virgin City, *Jones 5215* (US).

Arizona: Mohave Co., Beaver Dam, *R. H. Peebles 13083* (US).

Nevada: Clark Co., 12 mi. e. of Glendale, *Heiser, 4518* (IND); St. Thomas, *I. Tidestrom 9155* (US); *E. Palmer 243* (GH, NY); 14 mi. n. of Overton, *G. W. Gullion 557* (IND); 1 mi. w. of Logandale, *P. Train 1869* (MO); Churchill Co., 2 mi. e. of Frenchman's Station, *L. E. Mills* and *K. H. Beach C-10* (IND.); County not certain, Carson Desert, *S. Watson 600* (US).

The new species (fig. 1) is apparently most closely related to *H. anomalus* (fig. 2). Although it is quite different from the other annual species, it resembles *H. petiolaris* ssp. *fallax* more closely than the others. From *H. anomalus* it is distinguished by its smaller size which it maintains under greenhouse conditions, the green or red hispid stem in contrast to the whitish less pubescent stem of *H. anomalus*, the more numerous heads, the much shorter and more densely pubescent phyllaries, the smaller achenes which bear shorter hairs, and the shorter squamellae which are ovate instead of linear. Although only a small number of collections are known from both species, it appears that the two species are allopatric and that *H. deserticolus*, in general, grows at lower altitudes.

Since *H. anomalus* is a little known species it seems worthy to cite all the collections of it which have been seen by the author. The specimens were collected from May to October at altitudes of 4500 to 5000 ft.

Utah: Emery Co., San Raphael, *B. F. Harrison et al. 7434* (UTAH); Juab Co., 6 mi. n. of Lynndyl, *Harrison 11349* (US); Champlin, *Harrison 6548* (US); near Champlin, *Harrison 351 H* (MO); Wayne Co., s. of

1. This study has been aided by a grant from the National Science Foundation (G5860).

Figure 1

Fig. 1. *Helianthus deserticolus*, x ½. Achene with pappus, x 2½. Phyllary, x 1.

Figure 2

Fig. 2. *Helianthus anomalus,* x ½. Achene with pappus, x 2½. Phyllary, x 1. Drawing by Ruth Smith.

Hanksville, *W. D. Stanton 328* (TYPE, US), 17 mi. n.e. of Hanksville, *W. P. Stoutamire 2594* (US).

Arizona: Navajo Co., Hopi Indian Reservation, *D. K. Whiting 864/2730* (US); Old Oraibi *Heiser, 4163* (IND). County unknown; "Plants of the Hopis," *H. R. Voth 7* (CHI).

Of these plants all are fairly typical except *Harrison 351 H*, which shows some approach to *H. deserticolus*. The *Voth* specimen is unique in that some of the disks are 2.7 in diameter. The chromosome number of *H. anomalus* is also n = 17 (based on *Heiser 4163*).

The seeds of *H. deserticolus*, like those of *H. anomalus*, are extremely difficult to germinate and only five plants have been obtained from a total of over 100 achenes planted from three different sources. Crosses were attempted with *H. annuus*, *H. anomalus*, and *H. petiolaris* and a few seeds were obtained but these failed to germinate. The reciprocal combinations failed except for *H. petiolaris* x *H. deserticolus* which gave rise to one self. A cross between two strains of *H. deserticolus* (G 13—*Stoutamire 2594* x G 14—*Heiser 4518*) gave good seed set. One seed germinated which produced a plant showing 80% pollen fertility.

Forms of *Ceratium hirundinella* (O. F. Müller) Schrank in Lakes and Ponds of Indiana

W. A. Daily, Butler University

The algal genus, *Ceratium*, a dinoflagellate, is generally thought to contain four freshwater species. One of these, *C. hirundinella*, an open-water plankter, is the only species to have been found thus far in Indiana. This motile, unicellular alga has a state-wide distribution, or nearly so, in lakes and ponds, and there are herbarium specimens representing thirty-nine counties of a possible forty-eight from which we have plankton collections. The thirty-nine counties are located in the upper three-fourths of the state.

This study was begun recently in order to determine how many forms of *C. hirundinella* could be satisfactorily identified in our herbarium specimens, and to check the reliability of recently published descriptions of the forms. Several years ago, a thorough review was made of our plankton collections from about 300 lakes and ponds in order to note all the species of algae regardless of their individual abundance in the collection. It soon became apparent that *C. hirundinella* possesses infinite morphological variability and yet, could be arranged in groups sufficiently alike to warrant form epithets.

In Plate I are outline drawings of the four freshwater species of *Ceratium*. Fig. 1, *C. hirundinella* (O. F. Müller) Schrank (after Entz),

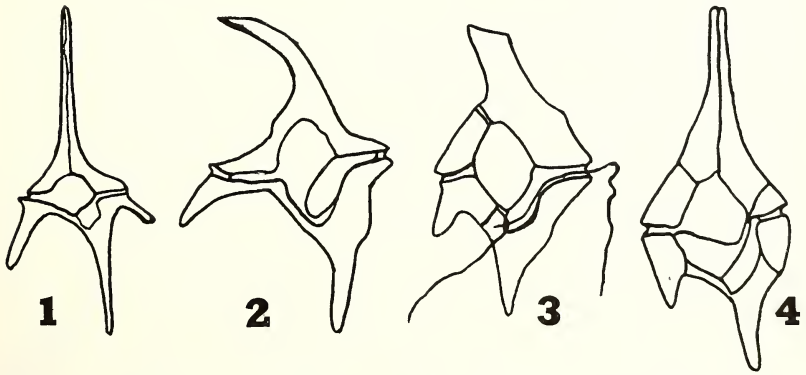


Plate I. Fig. 1. *Ceratium hirundinella* (O. F. Müller) Schrank. Fig. 2. *Ceratium carolinianum* (Bailey) Jorgensen (after Schilling). Fig. 3. *Ceratium cornutum* (Ehrenb.) Claparde & Lachman (after Schilling). Fig. 4. *Ceratium brachyceros* v. Daday (after Entz).

the only one found in Indiana to date, normally is composed of from 3 to 4 horns. The apical horn, which may be bent, is open at the tip, whereas, the others are closed. The cells vary from 100 to 350 microns in length. The width is about 40 to 55 microns. Fig. 2, *C. carolinianum* (Bailey) Jorgensen (after Schilling), a 3-horned species, is chiefly characterized by its bent and pointed apical cell. The length varies from 125 to 156

microns and the width from 70 to 105 microns. Fig. 3, *C. cornutum* (Ehrenb.) Claparede & Lachman (after Schilling), a 3-horned species, possesses a short, bent and truncated apical horn. The length varies from 95 to 150 microns and the width from 60 to 85 microns. Two flagella are shown here, one partly obscured by lying in the transverse furrow. Fig. 4, *C. brachyceros* v. Daday (after Entz), another definitely 3-horned species, and purely tropical (reported only from Africa and Asia) has an apical horn which is always straight. The length of the cells varies from 125-160 microns and the width from 40 to 55 microns.

These algae have fairly heavy reticulate ornamented walls and consist of 15 articulated plates, some of which are continued in horns. The epi- and hypovalves are separated by a transverse furrow or groove. Two flagella emerge from a flagellum plate on the ventral side of the cell. One of these is usually partially hidden in the transverse furrow.

C. hirundinella and *C. brachyceros* are open-water or free floating species. *C. carolinianum* and *C. cornutum* are generally shore species and often found intermingled with other water plants, namely, Chara and Lemna, but occasionally, they may be found in the open-water zone. Apparently, they are rare in the United States; however, both have been reported from Illinois.

Plate II portrays the four forms of *C. hirundinella* as found in Indiana. Fig. 1, f. *brachyceros* (v. Daday) Ostenfeld, a 3-horned plant,

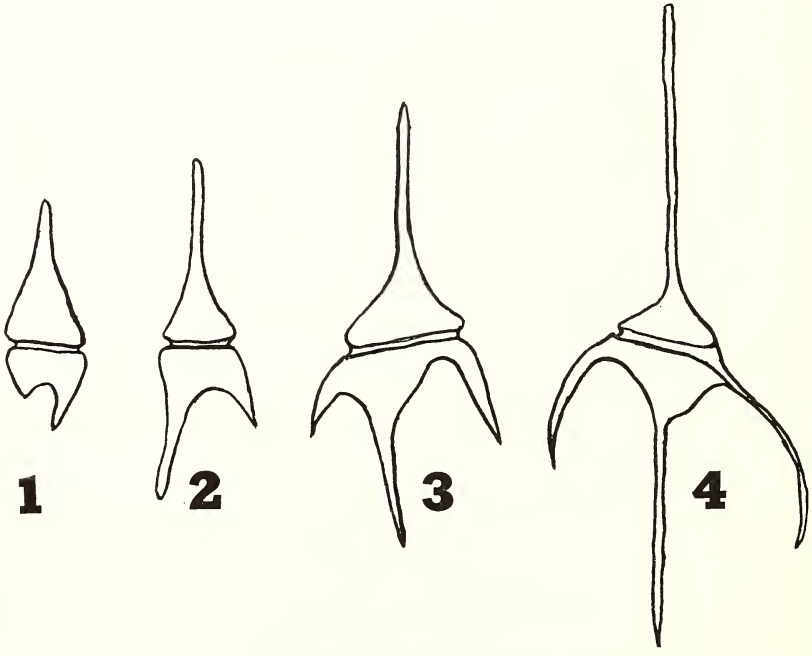


Plate II. Forms of *Ceratium hirundinella* (O. F. Müller) Schrank found in Indiana: Fig. 1, f. *brachyceros* (v. Daday) Ostenfeld; Fig. 2, f. *furcoides* (Entz) Schröder; Fig. 3, f. *robustum* (Amberg.) Bachman; Fig. 4, f. *piburgense* (Zdb.) Bachman.

is the smallest of the four forms, averaging 100 microns in length. The hypovalve, composed of two barely evident horns, is exceedingly short, and the epivalve narrows gradually to the apex. This form has been reported found chiefly in streams and rivers by Samuel Eddy. We have it in collections from Geist Reservoir and Lake Freeman whose water sources are mainly Fall Creek and Tippecanoe River respectively. The pH of the Geist Reservoir water ranges from 7.7 to 8.0 and this approaches the alkalinity of our northern Indiana lakes of glacial origin. However, this form has not been found in any of our lakes of the latter type. Morphologically, this form resembles very closely the species, *C. brachyceros*. Representative specimens in the writer's herbarium are numbered *1064*, 2524 (used for drawing), *2555* and *2603*.

Plate II, Fig. 2, f. *furcoides* (Entz) Schröder, intermediate in size (average—160 microns in length) has been found chiefly in gravel pits and small ponds. The horns are usually as shown here, but may be slightly curved and the antapicals converging instead of diverging. Representative specimens in the writer's herbarium are numbered **2560** (used for drawing) and *2656*.

Plate II, Figs. 3 and 4, forms *robustum* (Amberg.) Bachman and *piburgense* (Zdb.) Bachman respectively, both 4-horned, are primarily inhabitants of lakes of glacial origin here, e.g. Wawasee and Maxinkuckee. Each may be the only form present in a collection, but usually both are found together. Even though f. *piburgense* is shown by Huber-Pestalozzi (1) as having straight antapical horns, the name is used here for cells with two or three long, sickle-shaped antapical horns in the sense used by Bachman in 1911. Although he included both sickle-shaped and straight horns for the form, the Indiana forms seem to be all sickle-shaped, belonging otherwise to this category. Representative specimens in the writer's herbarium are numbered *2180, 2816;* and **D. G. Frey** (used for drawing), Round Lake, Steuben County. Form *robustum* has divergent antapical horns, but one of the three may be slightly curved. Representative specimens in the writer's herbarium are numbered *1013*, *2465*, *2519* and **2539** (used for drawing). The average length of f. *robustum* is about 200 microns, whereas f. *piburgense* is about 280 microns. These forms are found in more lakes than the first two and f. *robustum* is perhaps the most common of all.

Summary

1. There are four forms of *C. hirundinella* easily recognized in lakes and ponds of Indiana.

2. The criteria used for separation of the forms are the number and shape of horns and the total length of the cells.

3. In Indiana, forms *brachyceros* and *furcoides* are more often found in gravel pits and variously sized artificial lakes and ponds. Forms *robustum* and *piburgense* are more often found in lakes of glacial origin.

Literature Cited

1. HUBER-PESTALOZZI, G. 1950. Das Phytoplankton des Süsswassers. Die Binnengewasser 16 (3). *Ceratium,* pp. 260-283, Plate LXI.

PSYCHOLOGY

No meeting reported.

SOIL SCIENCE

Chairman: STANLEY A. BARBER, Purdue University

RONALD TUKEY, Purdue University, was elected chairman for 1961

ABSTRACTS

Evaporation and Solar Radiation in Indiana. LAWRENCE A. SCHAAL, Purdue University.—Solar radiation and evaporation measurements are relatively new in Indiana. Their use and likely applications in agricultural science are discussed. Statistical summaries are presented which estimate the variations of these measurements.

Predicting the Response of Corn to Subsoiling and Subsoil Fertilization. ANSON R. BERTRAND and RUSSELL FRAZIER, Purdue University.—Data from eight years of Subsoil Fertilization Experiments with corn in Indiana were analyzed by multiple factor analysis. The following four factors were found to account for 38.6% of the variation in yields: (1) Rainfall between November and May preceding the crops, (2) Drainage characteristics of the soil, (3) Potassium content of the subsoil, and (4) Phosphate content of the subsoil.

Correlation of Total Phosphorus Uptake with Different Phosphorus Soil Tests. M. F. BAUMGARDNER and A. F. GOLKE, Purdue University.—German millet was grown in the greenhouse as the indicator crop on 500 soils from many different areas in Indiana. One hundred millet plants were grown for 25 days in 100 grams of soil and 100 grams of washed quartz sand. The plants were harvested, dried, weighed, and analyzed for total phosphorus taken up from the soil. Five different extractants were used in testing the soils for available phosphorus:

Method	*Extractant*
a. Bray 1	0.025 *N* HCl and 0.03 *N* NH_4F
b. Bray 2	0.1 *N* HCl and 0.03 *N* NH_4F
c. Purdue	0.75 *N* HCl
d. Olsen	0.5 *M* $NaHCO_3$
e. Water	distilled water

The soil test data and the total plant phosphorus were then statistically analyzed to determine which phosphorus extractant gave the most satisfactory correlation with total plant phosphorus.

Evaluation of Three Sources of Nitrogen for Corn[1]

Russell K. Stivers, Dan Wiersma, and Javier Gil Flores,
Purdue University

Leaching of nitrogen from sandy northern Indiana soils is a problem when moisture is optimum for corn. Even though rainfall is seldom sufficient for corn, water for irrigation is generally available. Where irrigation water can be used, a material or method to supply nitrogen efficiently for corn throughout the growing season is important.

Armiger *et al.* (1) and Musser (2) found that the overall efficiency of properly formulated urea-form materials equals or exceeds that of conventional nitrogen fertilizers in respect to long season crops. Musser (2) also found that split applications of soluble nitrogen made at monthly intervals throughout the growing season gave growth responses similar to single applications of urea-form fertilizers on turf. Studies on the effect of urea-formaldehyde materials on cotton and corn were conducted by Scarsbrook (4) in Alabama. He compared these materials with a standard soluble source of ammonium nitrate. Yields of both cotton and corn increased with increasing rates of nitrogen from both sources. However, yields from the urea-formaldehyde fertilizer were equivalent to those produced on lots receiving only half as much nitrogen from ammonium nitrate. Both the nitrogen content in the sixth corn leaf at tasseling and the protein content of the grain at harvest were lower where urea-formaldehyde was the source of nitrogen.

The main purpose of these experiments was to evaluate the relative effect of a urea-formaldehyde source and two other common sources of nitrogen for corn under supplementary irrigation on Coloma sand.

METHODS AND PROCEDURES

Experiment I

This experiment was conducted on Coloma sand on the Sand Experiment Field near Culver, Indiana, in 1959. The soil is extremely drouthy when rainfall is either scarce or poorly distributed (Table 1). Irrigation

Table 1. Determination of Water Held by Coloma Sand at Field Capacity and at Permanent Wilting, Sand Experiment Field, Experiment I.

Depth in Inches	Inches of Water		
	Field Capacity	Permanent Wilting Point	Available Water
0–6	0.70	0.22	0.48
6–12	0.69	0.21	0.48

was used after 30% to 60% of the available soil water was depleted. Gravimetric soil moisture determinations and a soil moisture depletion curve were used to determine when to irrigate. Light weight aluminum

1. Journal Paper No. 1676, Purdue University Agr. Exp. Sta., Lafayette, Ind. Contribution from the Department of Agronomy.

portable pipes and overhead, circulatory sprinklers were used to apply the irrigation water. The amount of water applied per irrigation was determined as a function of time, spacing of sprinklers, and pressure. The total precipitation during June, July, and August was 6.62 inches, and the total amount of irrigation water applied was 14.50 inches (Table 2).

Table 2. Distribution and Amount of Precipitation and Irrigation in Inches During June, July, and August, 1959, Sand Experiment Field, Experiment I.

Date	Rainfall	Irrigation	Rainfall Plus Irrigation
June 8	....	2.00	
" 11	0.39	....	
" 12	0.10	....	
" 15	0.02	....	
" 16	0.01	....	
" 22	0.13	....	
" 23	....	2.00	
" 26	0.93	....	
" 30	0.02	....	
June total	1.60	4.00	5.60
July 1	0.34	1.50	
" 8	....	2.00	
" 17	0.52	1.00	
" 18	0.65	....	
" 19	0.66	....	
" 20	0.95	....	
" 23	0.33	....	
" 24	0.35	....	
" 28	0.02	....	
" 30	0.55	....	
July total	4.37	4.50	8.87
August 4	0.38	....	
" 6	....	2.00	
" 8	0.04	....	
" 16	0.03	....	
" 17	0.18	2.00	
" 22	....	2.00	
" 25	0.02	....	
August total	0.65	6.00	6.65
Three month total.	6.62	14.50	21.12

Even though drouthy, this Coloma sand was relatively high in soil pH and available phosphate and potash. Tests by the Purdue Soil Testing Laboratory showed the following:

Soil pH 6.5
Available P_2O_5, 0–6 inches.....Very High
Available P_2O_5, 6–12 inches.....Very High
Available K_2O, 0–6 inches.....Very High
Available K_2O, 6–12 inches.....High
Organic Matter, 0–6 inches.....1%

This soil had been used for growing sorghum under high fertility in 1957 and in 1958. A few days before planting, the experimental area was uniformly fertilized with 30 pounds per acre of available P_2O_5 from 48% superphosphate, 150 pounds of water soluble K_2O from 60% muriate of potash, and a mixture of minor elements. This mixture included 2 pounds per acre of zinc from zinc sulfate, 4 pounds per acre of manganese from manganese sulfate, 5 pounds per acre of copper from copper chloride, 10 pounds per acre of magnesium from magnesium sulfate, and 2 pounds per acre of boron from borax. After the experimental area was plowed, the fertilizer was drilled and then disked into the soil.

Two main variables were used in the experimental design. One was rate of nitrogen application, and the other was method or time of application. Three rates of nitrogen and five methods of application were used in fifteen different treatments. These treatments were arranged in a randomized split plot design with four replications. Rates of nitrogen composed the main plots, and methods of application were the sub-plots. Methods of application included three sources of nitrogen—urea, ammonium nitrate, and urea-formaldehyde—and two times of application—all at planting or five split applications. Sub-plots or methods of application were 35 feet long and four corn rows wide.

The urea with 45% nitrogen and the ammonium nitrate with 33% nitrogen are easily available from commercial sources. However, the urea-formaldehyde source used is not so readily available. The product used was called Nitroform, and it was supplied by Nitroform Agricultural Chemicals.[2] The available chemical data for nitroform were as follows:

Total nitrogen 38.1%
Cold water soluble nitrogen..... 11.9%
Cold water insoluble nitrogen..... 26.2%
Availability Index (AI)..... 35.0%

The first application of nitrogen in split application treatments was broadcast by hand on May 15. Four other applications of ammonium nitrate and urea used in split application treatments were applied: (1) at the first cultivation on June 8, (2) at the second cultivation on June 26, (3) on July 8, and (4) at the start of tasseling on July 18. These last four applications of ammonium nitrate and urea after planting were side-dressed. While the second and third applications were immediately followed by cultivations, the fourth and fifth applications were followed by irrigations.

The single application treatments of ammonium nitrate, urea, and urea-formaldehyde were also broadcast by hand on May 15. Then all

2. Courtesy of Professor W. H. Daniel, Turf Specialist, Agronomy Department, Purdue University.

plots were disked to mix the fertilizer within the top 3 to 4 inches of soil. A single cross hybred corn WF9 x OhO7 was planted in 38 inch rows on May 16. The rate of seeding was one kernel every 4 inches. On May 28 a 10% failure in emergence of the seedlings was noted. The blank spaces were immediately replanted by hand. After thinning on June 8, the final stand was one plant every 8 inches.

Leaf samples for nitrogen determinations were taken at tasseling. The sixth leaf above the ground was taken from 8 to 10 plants in the two center rows of each plot. These leaves were dried for 48 hours at 70° C. ground, and total nitrogen determined by the Kjeldahl method (3).

Yields were determined by harvesting and weighing the ears in the two center rows of each plot. Moisture content of the grain was determined by drying at a temperature of 105° C. for 24 hours. Yields were calculated on the basis of 56 pounds of shelled corn per bushel at 15.5% moisture, or number 2 corn. Tables were used to determine the pounds of ears required to shell a bushel at a particular moisture content.

Protein content of the corn grain was determined from composite samples of the four replications of each treatment. These grain samples were dried for 72 hours at 70° C., ground, and total nitrogen determined on the dry weight bases. Protein content was determined by multiplying the total nitrogen content by 6.25 (3).

Experiment II

This experiment was also conducted on Coloma sand on the Sand Experiment Field in 1959 very close to the area used for Experiment I. Irrigation was used to supplement rainfall during July and August as shown in Table 3. Tensiometer readings related to gravimetric soil moisture determinations were used to determine when to irrigate. More moisture stress was allowed in both June and July than was allowed in Experiment I before irrigation was initiated. The same irrigation equipment and method of determining amounts of water applied were used in this experiment as were used in Experiment I.

The area used for Experiment II had been in corn in 1957 and 1958. A uniform application of 180 pounds per acre of 60% water soluble K_2O was plowed down in spring. One hundred pounds per acre of Sul-Po-Mag containing 21% or more of water soluble K_2O was applied beside the row at planting. One hundred pounds per acre of 11-48-0 was also applied beside the row at planting.

The hybrid corn variety A.E.S. 601 was planted in 38 inch rows on June 1. Fifty pounds per acre of nitrogen from ammonium nitrate with 33% nitrogen was sidedressed on all plots on June 8.

Three different fertilizer sidedressing treatments were applied on June 26. One hundred pounds per acre of actual nitrogen was applied from each of three sources. Urea with 48% nitrogen, ammonium nitrate with 33% nitrogen, and 16-8-8 were sidedressed. Urea-formaldehyde was used to supply nitrogen in 16-8-8. Fifty percent of the nitrogen in the 16-8-8 was water soluble and 50% was not water soluble. Equivalent amounts of available phosphate and water soluble potash were sidedressed with the urea and ammonium nitrate so that all three treatments received equal amounts of plant food.

Table 3. Distribution and Amount of Precipitation and Irrigation in Inches During June, July, and August, 1959, Sand Experiment Field, Experiment II.

Period	Rainfall	Irrigation	Rainfall Plus Irrigation
1st week in June.....	0.00		
2nd week in June.....	0.49		
3rd week in June.....	0.03		
4th week in June.....	1.30		
June total	1.82	0.00	1.82
1st week in July.....	0.36	1.50	
2nd week in July.....	0.00		
3rd week in July.....	1.83	2.00	
4th week in July.....	1.63		
5th week in July.....	0.57		
July total	4.39	3.50	7.89
1st week in August....	0.42	2.00	
2nd week in August....	0.03		
3rd week in August....	0.18	2.00	
4th week in August....	0.02	2.00	
August total	0.65	6.00	6.65
Three Month Total....	6.86	9.50	16.36

The three different fertilizer sidedressing treatments were arranged in three randomized replications. The plots used in these replications were 4 corn rows wide and 150 feet long.

Sampling of the corn leaves and nitrogen analyses were accomplished the same as in Experiment I. Yields of shelled corn were weighed from the two center rows of each plot, moisture determined as in Experiment I, and yields calculated on the basis of 56 pounds of grain per bushel with 15.5% moisture.

RESULTS AND DISCUSSION

Experiment I

Foliar symptoms of nitrogen deficiency were evident during the latter part of the growing season. They were most evident on the 80 pounds per acre rate of nitrogen, particularly on the urea-formaldehyde treatments. The leaves of corn in the 160 and 240 pound per acre rates of nitrogen from urea-formaldehyde were lighter green than those from urea and ammonium nitrate with comparable rates.

Corn height on June 23 (Table 4) and on July 28 (Table 5) was less at the 80 pound per acre rate of nitrogen than at the higher rates. There was a definite trend for the 80 pound rate of nitrogen treatments and for the urea-formaldehyde treatments to have fewer ears per 100 corn plants (Table 6) and lower ear weights (Table 7). The ear weights averaging

Table 4. Corn Height in Inches on June 23, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	20	16	20	18	17	18
160	21	20	21	22	18	20
240	22	23	21	23	21	22
Average	21	20	21	21	19	

Table 5. Corn Height in Inches on July 28, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	97	98	97	99	88	96
160	103	106	105	105	100	104
240	105	106	106	107	105	106
Average	102	103	103	104	98	

Table 6. Numbers of Ears per 100 Corn Plants as Affected by Treatment, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	76.6	91.1	79.1	93.4	72.2	82.5
160	89.6	102.0	89.7	100.0	81.3	92.5
240	100.0	100.0	93.5	100.0	81.3	95.0
Average	88.7	97.7	87.4	97.8	78.3	

Table 7. Average Ear Weights in Pounds at 15.5% Moisture as Affected by Treatment, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	0.29	0.25	0.28	0.27	0.14	0.25
160	0.35	0.32	0.34	0.34	0.24	0.33
240	0.35	0.34	0.35	0.36	0.30	0.34
Average	0.33	0.30	0.32	0.32	0.23	

from .14 to .36 pound were all too low, since .50 pound per ear is considered the ideal. Evidently, the population of stalks per acre was too high. However, it was approximately the same for all treatments (Table 8).

Table 8. Observed Population at Harvest in Thousands of Plants Per Acre, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	20.1	20.7	18.8	19.9	18.8	19.7
160	20.1	20.4	20.4	20.7	19.6	20.2
240	18.3	20.1	20.4	20.4	19.6	19.8
Average	19.5	20.4	19.9	20.3	19.3	

The average nitrogen percentage of the sixth leaf of the urea-formaldehyde treatments was significantly lower than those of all other sources (Table 9). This trend was quite evident at all three nitrogen

Table 9. Nitrogen Content of Sixth Leaf of Corn at Tasseling Stage in Percent, Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs./A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	1.96	2.12	1.69	2.32	1.41	1.90
160	2.46	2.76	2.65	2.64	1.88	2.48
240	2.70	2.76	2.77	2.63	2.09	2.59
Average	2.37	2.55	2.37	2.53	1.79	

Significant difference at the 5% level

Between two levels of nitrogen	0.28
Between two methods	0.12
Between two methods, at the same level of nitrogen	0.29
Between two levels of nitrogen, at the same method	0.35

levels. Also, the average nitrogen percentages were significantly higher with five applications than with one equivalent application at planting. This was true for both the ammonium nitrate and the urea sources.

The average yield of corn with five applications of urea was significantly higher than that with one application (Table 10). A trend in favor of the five applications over one application also was evident at all levels with ammonium nitrate. Yields of all treatments with urea-formaldehyde were significantly lower than those of both urea and ammonium nitrate for both one and five applications. Yields increased significantly from the 80 pound to the 160 pound per acre level of nitrogen in all five methods. Even though the increases from 160 pounds to 240 pounds per acre were

Table 10. Corn Yields in Bushels of Grain Per Acre (15.5% Moisture), Sand Experiment Field, 1959, Experiment I.

Level of Nitrogen Lbs/A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	73.9	76.0	70.4	86.7	32.0	67.8
160	104.0	111.9	105.5	113.4	62.0	99.4
240	104.8	111.1	111.3	116.2	80.6	104.8
Average	94.2	99.7	95.7	105.4	58.2	

Significant difference at the 5% level

Between two levels of nitrogen	13.6
Between two methods	6.5
Between two methods, at the same level of nitrogen	11.3
Between two levels of nitrogen, at the same method	18.3

not significant in four of the five methods of application, there was a trend in this direction.

The relationship between yields and percent nitrogen in the sixth leaf at tasseling stage was measured by the calculation of a regression coefficient. The calculated regression coefficient value was 5.3 or an average increase of 5.3 bushels of corn per 0.1% increase in nitrogen content of the sixth leaf. The correlation coefficient was .499, significant at the 6% level with 13 degrees of freedom.

Percentages of protein in the grain tended to increase with increasing rates of nitrogen with one exception (Table 11). The protein content of

Table 11. Percentage of Protein in Corn Grain as Affected by Nitrogen Treatments, Sand Experiment Field, 1959, Experiment I

Level of Nitrogen Lbs/A	Source of Nitrogen and Number of Applications (Method)					
	Ammonium Nitrate		Urea		Urea-Formaldehyde	
	One Applic.	Five Applic.	One Applic.	Five Applic.	One Application	Average
80	5.98	6.29	5.82	6.04	6.43	6.11
160	7.62	8.41	7.17	8.76	6.29	7.65
240	8.06	8.83	8.08	8.74	6.33	8.01
Average	7.22	7.84	7.02	7.85	6.35	

the grain from the three urea-formaldehyde treatments appeared to be about the same. An explanation for this lack of increase in protein has been given by Zuber, Smith, and Gehrke (5). They said that probably there would be substantial increases in percentage nitrogen in corn grain only where nitrogen is present in amounts above optimum.

Experiment II

Neither nitrogen percentage in the sixth leaf at tasseling nor yields showed any significant differences related to treatment (Table 12). The

Table 12. Nitrogen Content of Corn Leaves at Tasseling and Yield of Corn, Sand Experiment Field, 1959, Experiment II.

Sources of Nitrogen Sidedressed on June 26 at the Rate of 100 lbs N/A	Nitrogen Content of Leaves at Tasseling Time (July 14) %	Yield of Corn at 15.5% Moisture bu./A.
48–0–0 *	2.71	87.5
33–0–0 *	2.65	89.4
16–8–8	2.78	85.9
Least Significant Difference	Not Significant	Not Significant

* Equivalent amounts of P_2O_5 and K_2O were sidedressed on the first two treatments when 16-8-8 was sidedressed on the third treatment.

nitrogen content of the sixth leaf was high enough to indicate that there was enough nitrogen for higher yields had other conditions been better. However the lower leaves of the treatments with 16-8-8 containing urea-formaldehyde showed a deficiency of nitrogen while the other sources did not. The population of 19,000 stalks per acre at harvest was high enough to allow a much higher yield. The late planting date of June 1 no doubt prevented higher yields. There is some likelihood that lack of irrigation in June slowed down early growth of the corn.

Summary

Urea-formaldehyde was compared with urea and with ammonium nitrate as a source of nitrogen fertilizer for irrigated corn. Two different experiments comparing these fertilizers were conducted on Coloma sand in northern Indiana in 1959. In one experiment no meaningful differences among treatments were obtained, probably because of the relatively low yields of less than 90 bushels per acre. In the other experiment average yields of the better treatments ranged from 104 to 116 bushels per acre.

In the latter experiment urea-formaldehyde was not as good as urea or ammonium nitrate as a nitrogen fertilizer. Both the average percentage of nitrogen in the sixth corn leaf at tasseling and the average yield of grain were significantly lower with urea-formaldehyde than with the other two nitrogen fertilizers. There was a definite trend for split applications of urea and ammonium nitrate to be better than a single application of the same total amount of nitrogen at planting. Percentage of nitrogen in the sixth corn leaf and yields of grain tended to increase from 80 to 240 pounds per acre of applied nitrogen fertilizer. However, only the increase in yield from 80 to 160 pounds per acre of nitrogen was large and significant.

Literature Cited

1. Armiger, W. H. et al. Urea-Form: Greenhouse Studies with Perennial Ryegrass. Jour. Am. Soc. Agr. 43: 123-127. 1951.
2. Musser, H. B. Tests of Urea-Formaldehyde and Other Nitrogenous Fertilizers for use on Turf. Penn. State College Bul. 542. 1953.
3. Official Methods of Analysis of the Association of Official Agricultural Chemists. Eighth Edition. A. O. A. C., Washington, D. C. 1955.

4. SCARSBROOK, C. E. Urea-Formaldehyde Fertilizer as a source of Nitrogen for Cotton and Corn. Soil Sci. Soc. Am. Proc. 22 : 442-445. 1958.

5. ZUBER, M. S., SMITH, G. E., and GEHRKE, C. W. Crude Protein of Corn Grain and Stover as Influenced by Different Hybrids, Plant Populations, and Nitrogen Levels. Agr. Jour. 46 : 257-261. 1954.

The Effect of Soil Depth and Soil Volume Upon Corn Yield in a Greenhouse Experiment[1]

S. D. Evans and S. A. Barber, Purdue University

The growth of plants depends both upon above-ground level factors such as light, CO_2 and temperature and below-ground level factors such as water, nutrients, aeration and space for the plant roots to grow.

The rooting volume was the factor selected for study in the research presented in this paper. Much of the previous research on this factor has not separated differences which may be due to added nutrients as well as added volume in which the plant was growing.

Investigators (1,2,3) have worked with different sizes and shapes of containers in order to determine the best size to use for greenhouse experiments. In a paper concerning techniques which might help to make greenhouse experiments comparable with field plot experiments, Cook and Millar (3) state that greenhouse containers should be large so that differences between treatments are minimized. They say this is because of the limitation of root growth in some treatments and not in others when small containers are used. Cook and Millar (3) state that for many experiments 1- or 2-gallon jars are too small. Their interpretation would indicate that the volume available for root growth influences the yield.

Arminger and co-workers (1) found that for alfalfa, and quite probably for a number of other plants, greenhouse tests could be conducted just as accurately in small containers that ranged in volume from 1-gallon to 3-gallons as in large containers.

Arminger and Fried (2) used different sizes and shapes of containers in which the plant population of each was proportional to the weight of soil they contained. They also investigated the effect on plant growth that may have been caused by a varying ratio of a container's surface area relative to its depth of soil. Both yield and nutrient uptake data indicated that when plant population was proportional to weight of soil, smaller containers, 1-gallon or less, gave larger plants containing more phosphorus than did the larger containers. Further they found that the yield obtained reflected the surface area to a greater extent than the weight of soil in the pot.

The objective of this research was to determine the effect of volume available for root growth and soil depth upon crop growth. The volume available for root growth varied by using different amounts of soil and by replacing soil with sand.

Experiment I

This experiment was designed to investigate the influence of both soil depth and soil volume on plant growth using corn as the indicator crop. The soil phosphorus level was also varied to determine the effect of soil depth and volume on supplying phosphorus to the plant as well as their effect on growth itself.

Paper No. 1677 Purdue University Agricultural Experiment Station, Lafayette, Indiana. Contribution from the Department of Agronomy. This research was supported by a grant-in-aid from the Allied Chemical Corporation.

Materials and Methods

The soil used, Sidell silt loam, had a pH of 5.5, an available phosphorus level of 11 pp2m, and an available potassium level of 102 pp2m. Both of these levels were obtained by the Purdue method. The soil organic matter level was also very low. The soil was limed to pH 6.8. Three hundred pounds per acre of nitrogen and 332 pounds per acre of potassium were added to each pot. The corn was grown in #10 cans.

The treatments were arranged in a 2 x 3 x 4 factorial which consisted of with and without three inches of washed silica sand below the soil, soil depths of 3, 6 and 9 inches, and phosphorus fertilization rates of 0, 44, 87 and 131 pp2m of phosphorus. An extra treatment was added which had 12 inches of soil. All treatments were replicated twice. The moisture level was maintained fairly constant by weighing the pots regularly and bringing them back to field capacity by the addition of water.

The corn was harvested after 6½ weeks and dry weight, phosphorus content and potassium content were determined.

Results and Discussion

The weights of the tops in grams are shown in Table 1. Increased volume available for root growth by adding sand, increased soil depth,

Table 1. The effect of soil depth, phosphorus fertilization and sand on the growth of corn.

	Weight in grams							
	No sand				Sand *			
P rate	Soil depth				Soil depth			
pp2m	3″	6″	9″	Sum	3″	6″	9″	Sum
0	7.6	14.4	17.8	39.8	9.8	16.8	17.4	44.0
44	8.4	15.6	20.2	44.2	14.4	21.8	22.2	58.4
87	7.6	17.4	21.8	46.8	15.8	22.8	28.2	67.8
131	9.4	19.7	23.6	52.7	16.5	20.6	28.4	65.5
Sum	33.0	67.1	83.4	183.5	56.5	82.0	97.2	235.7

* 3 inches of sand below the soil

LSD 5%-2.8

LSD 1%-3.8

and increased phosphorus concentration produced highly significant increases in dry weight.

Increased volume available for root growth by adding three inches of sand beneath the soil increased the average dry weight of the tops from 15.3 grams to 19.6 grams. This appeared to be due to the increased rooting volume, because the bottoms of the cans were perforated to follow the excess moisture of drain out and inspection of the root systems at the end of the experiment showed that the roots had thoroughly penetrated the sand.

The average dry weight per pot for 3 inches of soil was 11.2 grams, for 6 inches of soil 18.6 grams, and for 9 inches of soil 22.4 grams. The effect of depth is shown in Figure 1. The top line indicates the treatments

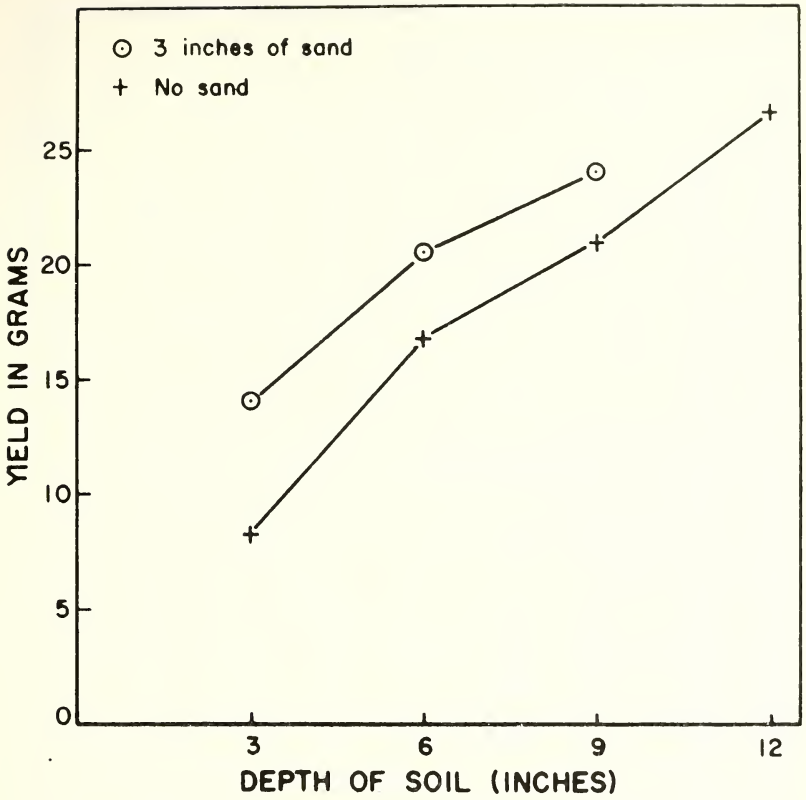


Figure 1. Effect of soil depth upon yield of corn in grams per pot.

with three inches of sand below the soil and the bottom line indicates the treatments without the sand. These lines are approximately parallel, and their displacement indicates that three inches of sand is approximately as effective as three inches of soil. The rate of increase in dry weight with increasing soil depth was approximately the same whether three inches of sand was present or not.

The increase in the amount of phosphorus applied also increased dry weight. The average dry weights for 0, 44, 87, and 131 pp2m of phosphorus were 14.0, 17.1, 18.9 and 19.2 grams respectively. The increase in yield due to phosphorus fertilization is shown in Figure 2. These values were obtained by subtracting the yield in the check pot from those of the phosphorus treated pots at each depth. The increase for the first 33 mgms. of phosphorus added was much greater when sand was present than when it was not. The increase per unit of phosphorus added after this initial rise with the sand was almost the same with and without sand. The increase per unit of phosphorus added was constant for each soil depth and was dependent on the total phosphorus added per pot rather than per unit of soil.

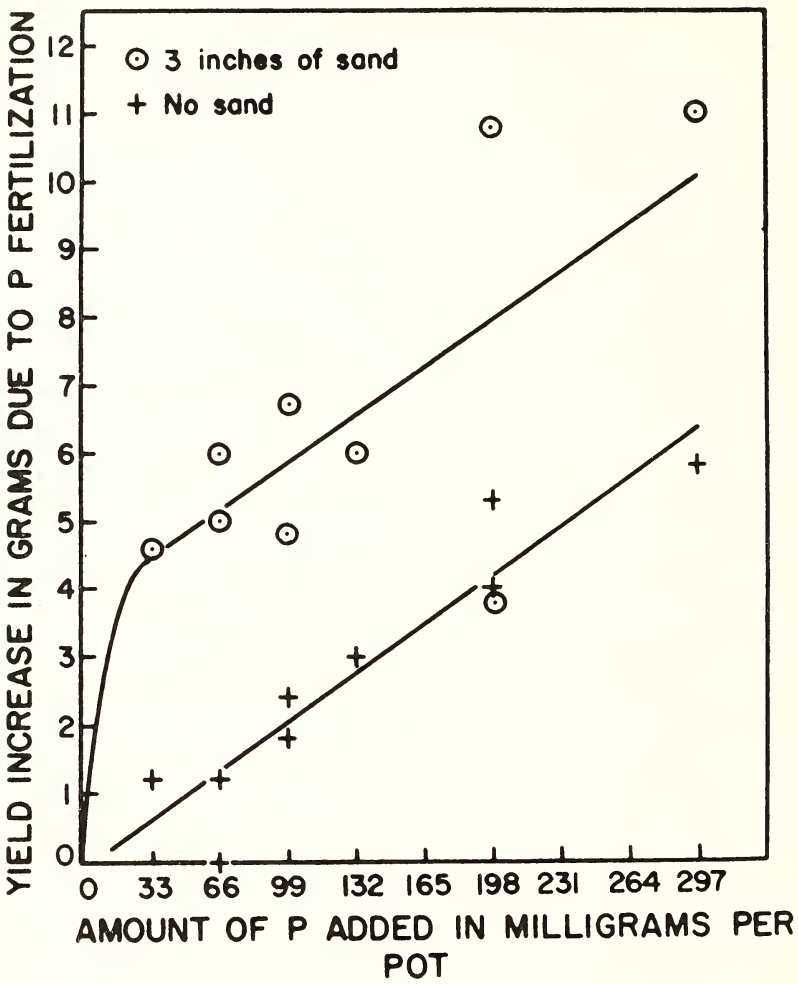


Figure 2. Effect of phosphorus fertilization on yield of corn.

The plant material was analyzed for phosphorus content and the values are given in Table 2. The percentage phosphorus at the 131 pp2m rate of phosphorus fertilization was less than at the 87 pp2m rate indicating that phosphorus was not the factor limiting yield. Phosphorus uptake in grams was the same or less at the 87 pp2m rate as that at the 131 pp2m rate in 4 of 6 cases, again indicating that phosphorus was not limiting yield at these rates.

Increased volume available for root growth, increased soil depth, and increased amount of phosphorus added decreased percentage potassium significantly as shown in Table 3.

These effects were significant at the 1% level. This indicates that potassium was not the factor limiting yield because the percentage potas-

Table 2. The effect of soil depth, phosphorus fertilization and sand on the percentage phosphorus of corn.

P rate pp2m	Percentage Phosphorus No sand Soil depth 3″	6″	9″	Sum	Sand * Soil depth 3″	6″	9″	Sum
0	.124	.113	.146	.383	.079	.119	.130	.328
44	.166	.149	.142	.457	.120	.175	.160	.455
87	.192	.192	.186	.570	.140	.172	.166	.478
131	.154	.184	.174	.512	.153	.134	.158	.445
Sum	.636	.638	.648	1.922	.492	.600	.614	1.706

* Three inches of sand below the soil

LSD 5%-.028

LSD 1%-.039

Table 3. The effect of soil depth, phosphorus fertilization and sand on the percentage potassium of corn.

P rate pp2m	Percentage Potassium No sand Soil depth 3″	6″	9″	Sum	Sand * Soil depth 3″	6″	9″	Sum
0	3.88	2.78	2.45	9.11	2.90	2.32	2.40	7.62
44	3.12	2.32	2.08	7.52	2.30	1.70	2.00	6.00
87	3.60	2.10	1.85	7.55	2.05	1.70	1.62	5.37
131	3.50	1.92	1.75	7.17	1.98	1.95	1.52	5.45
Sum	14.10	9.12	8.13	31.35	9.20	7.67	7.54	24.44

* Three inches of sand below the soil

LSD 5%-0.46

LSD 1%-0.64

sium was high at the low yield levels and decreased as dry weight increased. Grams of potassium taken up increased significantly with increasing soil depths. This increase was not all due to the exchangeable potassium present in the soil, because the pots with 3 inches of soil had 672 mgms. of exchangeable potassium, with 6 inches 741 mgms., and with 9 inches 810 mgms. This data also indicates that potassium was not limiting yield.

The following conclusions may be drawn from this experiment. First, increasing the volume available for root growth by adding 3 inches of sand below the soil increased dry weight and phosphorus uptake. It decreased percentage phosphorus and potassium significantly. This decrease in percentage phosphorus and potassium while dry weight increased indicates that these two elements were not limiting yield.

Second, changing the soil depth from 3 inches to 9 inches increased dry weight, percentage phosphorus, phosphorus uptake, and potassium uptake. It decreased percentage potassium. This increase in the phosphorus content of the plant samples was not due to the increased amount of available phosphorus added by the soil, since this amounted to approxi-

mately 20 mgms. per 3 inches of soil whereas the average increase in uptake was 30 mgms. per 3 inches of soil. All pots were adequately fertilized with potassium and the increased potassium uptake with depth was greater than the exchangeable potassium added with increased soil depth. Therefore this increase in potassium uptake can not be attributed to more potassium being added by the soil. Also, since percentage potassium decreased with increasing soil depth, the indication is that potassium was not limiting yield.

Third, increasing the phosphorus added to the soil increased dry weight, percentage phosphorus and phosphorus uptake, and decreased percentage potassium. Where the same amount of phosphorus was present in two different volumes, phosphorus uptake was always greater in the larger volume. This indicates that volume is a very important factor in determining yield and also in determining the availability of added phosphorus.

Experiment II

In the first experiment it was found that the increase in yield with increasing soil volume was apparently not due to increases in either available phosphorus or potassium. A second experiment was designed to determine if this increase was due to the increase in soil depth, to the increase in the soil volume, or due to other elements being supplied by the added quantities of soil.

Materials and Methods

The treatments were arranged in a 3 x 5 factorial with three soil depths of 8.8 inches, 12.0 inches, and 17.3 inches, all having the same soil volume brought about by changing the pot diameter, and five soil:sand mixtures of 1:0, 1:.20, 1:.66, 1:1.5 and 1:4. The soil used was Sidell silt loam, the same as used in the first experiment. The soil was limed to pH 6.8. Three hundred pp2m of nitrogen, 131 pp2m of phosphorus, and 124 pp2m of potassium were applied. The rate of nitrogen used was the same as used in the first experiment, while the amount of potassium was less. The amount of phosphorus was the same as used at the highest level in the first experiment. All fertilizer rates were calculated using the total volume of soil plus sand. The indicator crop used was corn. After a growing period of 5½ weeks, dry weight and potassium content were determined.

Results and Discussion

Soil depth had no significant effect on dry weight as shown in Table 4. Soil:sand ratio significantly affected dry weight with a 1:4 soil:sand ratio giving the largest yields.

There were differences in percentage potassium and potassium uptake between treatments, but there were no significant trends due to either soil depth or soil:sand ratio. The following conclusions may be drawn from this experiment. Soil depth and soil:sand ratio had no effect on yield within the limits used so long as rooting volume remained constant. Soil:sand ratio did not affect the ability of the corn plant to get adequate potassium nor did it affect the amount taken up. This would indicate that the soil did not supply any nutrient to increase yields in this case and thus the increases due to greater soil depths found in the first experiment can be attributed to volume available for root growth.

Table 4. The effect of soil depth and soil:sand ratio on corn growth.

Soil depth	1 : 0	1 :.20	1 :.66	1 : 1.5	1 : 4	Sum
8.8″	10.90	11.92	10.16	9.37	13.95	56.30
12.0″	12.41	10.64	9.82	11.74	13.53	58.14
17.3″	12.41	6.95	9.88	10.09	13.69	53.02
Sum	35.72	29.51	29.86	31.90	41.17	167.46

LSD-5%-2.93

LSD-1%-3.95

Literature Cited

1. Arminger, W. H., Dean, L. A. Mason, D. D. and Koch, E. J. Effects of size and type of pot on relative precision, yields, and nutrient uptake in greenhouse fertilizer experiments. Agron. Jour. **50** : 244-247, 1958.
2. Arminger, W. H., and Fried, M. Effect of pot size and shape on yield and phosphorus uptake of millet. Agron. Jour. **50** : 462-465, 1958.
3. Cook, R. L., and Millar, C. E. Some techniques which help to make greenhouse investigations comparable with field plot experiments. Soil Sci. Soc. Amer. Proc. **11** : 298-304, 1946.

Pot Culture—An Aid to Site Evaluation

F. Bryan Clark, U. S. Department of Agriculture, Forest Service, Central States Forest Experiment Station, Bedford, Indiana

Most hardwood plantings on old fields in southern Indiana and adjacent areas have failed. In order to find the reasons for this failure, a way was sought to evaluate the effects of various soil factors on seedling growth. Such factors as soil structure, organic matter content, and microorganism populations can be measured, but the relative effects of individual or combined factors are difficult to determine because no common denominator is available. The problem was to find a way to manipulate these various soil characteristics under controlled conditions so that their influence on seedling growth could be determined.

Methods

To get this job done large cores of undisturbed soil were collected in gallon cans. These cans then served as pots for growing seedlings. Salvaged number 10 tin cans which are about 6 inches in diameter and 7 inches high were used. To take a sample the open top of the can was pressed firmly against the soil surface and the litter cut by tracing the outline of the can with a trowel or knife. The can was driven flush to the surface with a sledge hammer and a 2-inch-thick block of wood (fig. 1). A small hole punched in the can bottom allowed the air to escape. The can was dug from the ground with a shovel and the excess soil shaved off the core bottom with a trowel. The best time for taking samples was when the soil was moist, near field capacity. Stones, roots, and very tight soil caused some loss of cans. In a forest soil practically free of stone, about half of the cans were ruined because of roots. When the cores were ready for treatment and planting the can bottoms were removed with a can opener leaving the undisturbed soil core enclosed in a tin sleeve.

To find out if the cores taken as described would produce differential growth responses in tree seedlings, two trial runs were made. Cores were taken in Zanesville silt loam on a broad ridge under four different cover types: (1) an old field, (2) a 22-year-old shortleaf pine (*Pinus echinata* Mill.) plantation, (3) a 22-year-old black locust (*Robinia pseudoacacia* L.) plantation, and (4) a second-growth, mixed-hardwood stand. The old field and plantations were originally parts of the same abandoned field. The plantations and the forest stand were well stocked with complete crown closure, while the old field contained a sparse cover of weeds and grass.

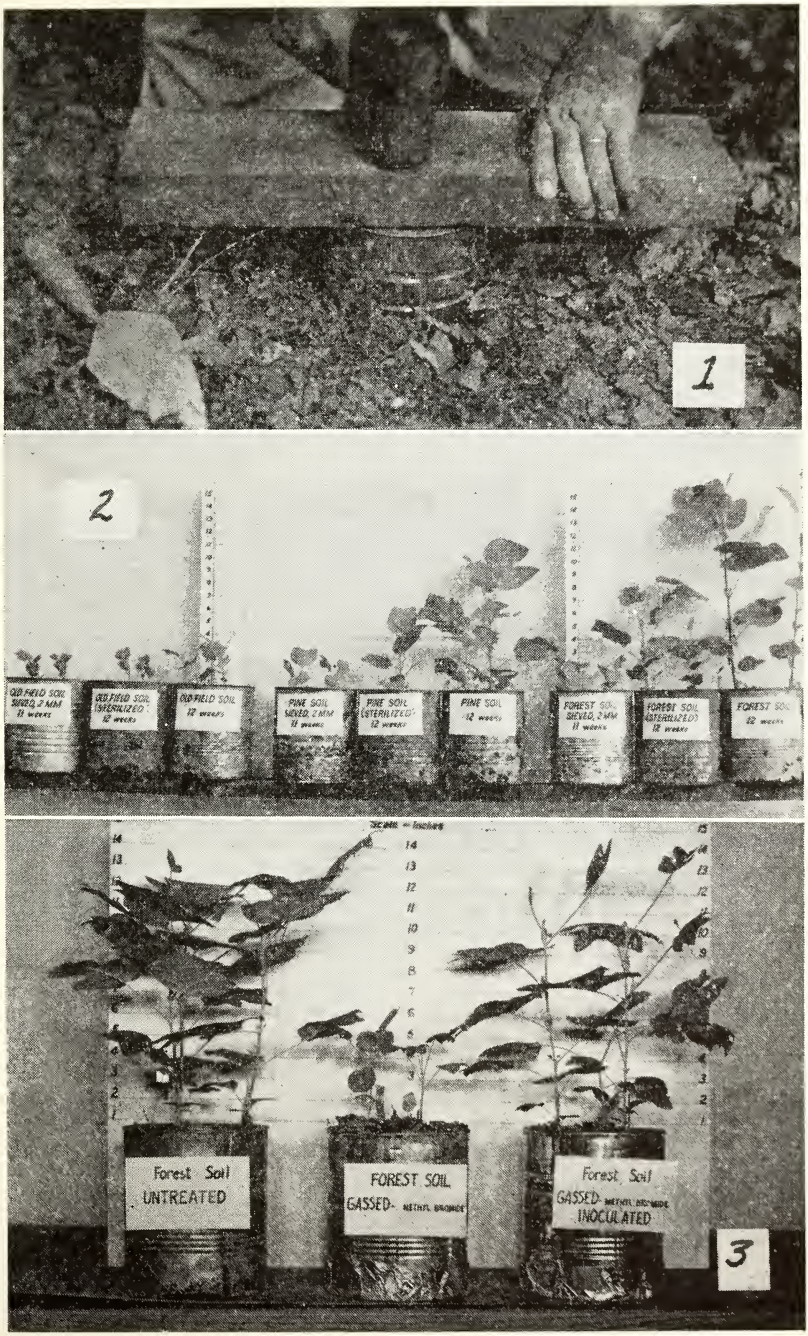
Soil cores from some of the sites were broken up and sieved through a 2-mm. screen to destroy macrostructure. Another series of cores was

---

Figure 1. After the litter is cut the can is driven flush to the soil surface.

Figure 2. Growth differentiation of yellow-poplar seedlings by sites and treatments has been striking (scale in inches).

Figure 3. Seedlings grown in sterilized pots were much smaller than seedlings gown in untreated pots. Inoculation shows that microorganisms and not toxicants or change in soil structure are related to differences in growth (scale in inches).


1
2
OLD FIELD SOIL SIEVED, 2 MM 11 WEEKS
OLD FIELD SOIL STERILIZED 12 WEEKS
OLDFIELD SOIL 12 WEEKS
PINE SOIL SIEVED, 2 MM 11 WEEKS
PINE SOIL STERILIZED 12 WEEKS
PINE SOIL 12 WEEKS
FOREST SOIL SIEVED, 2 MM 11 WEEKS
FOREST SOIL STERILIZED 12 WEEKS
FOREST SOIL 12 WEEKS
SCALE = Inches
Forest Soil UNTREATED
FOREST SOIL GASSED- METHYL BROMIDE
Forest Soil GASSED- METHYL BROMIDE INOCULATED
3

Figures 1, 2 and 3

sterilized by three different methods to find a technique that would kill micro-organisms but would not change soil structure. The three methods were: heating at about 180° C for 1 hour, autoclaving at 104° C under 4 pounds pressure for 1 hour on each of 3 successive days, and gassing with methyl bromide in a closed container. Half of the autoclaved and gassed forest-soil cores were inoculated with untreated forest soil. Inoculation was done by punching three holes in the soil core with a metal tube ⅜ inch in diameter and filling the holes with plugs of untreated forest soil. Several newly germinated yellow-poplar seeds were planted in each pot. This species was selected for study because it is very sensitive to differences in soil. When the plants were well established, the seedlings were thinned to three per pot.

The first trial was made outdoors in full sunlight and the second in a laboratory under artificial light on a 14-hour day. After 12 weeks the seedlings were removed from the pots by soaking and washing in running water. Top and root length were measured and green tops and roots were weighed.

Results and Discussion

Results were striking and differentiation of growth by treatment was excellent (fig. 2): many differences among sites and treatments were statistically significant at the 1 percent level. Although the actual size of the seedlings means little, comparing heights among sites and treatments is a simple way to show the relative effect of various site factors on tree growth. For example, in the first trial seedlings grown in untreated forest soil were 4 times taller and 12 times heavier than seedlings grown in untreated old-field soil (table 1). Results of the second trial were practically the same where treatments were comparable.

TABLE 1

Size of seedlings grown 12 weeks in full sunlight by sites and soil treatment

Site and Treatment	Top Length[1]	Total Green Weight[1]
	inches	grams
FOREST SITE		
Untreated	8.8	10.9
Sterilized[2]	3.9	2.8
Sieved[3]	1.9	1.0
PINE SITE		
Untreated	4.7	4.8
Sterilized	2.6	1.3
Sieved	2.0	1.1
OLD FIELD SITE		
Untreated	2.0	0.9
Sterilized	1.4	0.6
Sieved	1.6	0.8

1. Mean value of 6 replications of 2 seedlings each.
2. At 180° C for 1 hour.
3. Seedlings grown in sieved soil were 11 weeks old.

Seedlings grown in inoculated, sterilized forest soils were as large as seedlings grown in untreated forest soils (fig. 3). Therefore, results were not due to toxicants produced during sterilization or to the destruction of soil structure by sterilization. Seedlings growing in sterilized pots were chlorotic while all others had good color, suggesting that the destruction of soil organisms was probably detrimental to seedling nutrition.

These preliminary tests demonstrate that large, undisturbed soil cores can be used to study various factors affecting seedling growth in the laboratory. Thus the uncertainties of climate can be greatly reduced. The method could be useful to soil scientists, foresters, horticulturists, plant physiologists, and plant pathologists. Variables other than those tested could be studied. Comparisons could be made among and within soil types, cover types, or treatment types. Response to fertilizer or chemical application could be observed in the laboratory. So far, only the top 7-inch layer of the soil profile has been studied, but there is no reason why lower parts of the profile cannot be sampled by first removing the upper horizons.

The Molybdenum Status of Some Indiana Soils[1]

TERRY LAVY, GERALD SANDS and STANLEY BARBER, Purdue University

Molybdenum was first shown to be essential for plant growth in 1939 by Arnon and Stout (3). Previous efforts by other workers failed because of molybdenum impurities in the chemicals used in the nutrient solutions. Using tomatoes as the indicator crop, Arnon and Stout found that adding molybdenum at the rate of one part per 100 million parts nutrient solution allowed good plant growth.

The first plant response to molybdenum added to the soil was reported by Anderson (1) in Australia in 1942. He found that molybdenum applications of one ounce per acre produced large yield responses in subterranean clover. Later investigators both in Australia and the United State reported molybdenum response also with non leguminous plants. Bortels (5) had previously shown that the presence of molybdenum was essential in symbiotic nitrogen fixation.

Evans, Purvis and Bear (6) while working with molybdenum deficient plants noticed a nitrate build-up. Upon addition of molybdenum to the growing media this accumulation of nitrates was not found. It was suggested that nitrate build-up may be an indirect effect caused by a lack of molybdenum in a reaction preliminary to nitrate reduction.

In attempting to find molybdenum deficiencies it is first important to understand the different molybdenum forms occurring in the soil. Igneous rocks have been shown to contain less than 1 PPM molybdenum (6). As weathering of the rock occurs molybdenum is released. Being a transition element molybdenum has valence states ranging from +2 to +6, therefore it is capable of being tied up in many chemical compounds.

Barshad (4), in attempting to characterize soil molybdenum, postulated that molybdenum in the soil is present not just as a distinct mineral, but rather partly as a molybdate salt, partly as a component of organic matter and partly as an adsorbed exchangeable anion. This exchangeable anion is the molybdate ion, $MoO_4^{=}$, which is the form available for plant uptake.

Stout (9) points out that the molybdate ion should act like the sulfate ion due to its similarity in charge and size. This ion has been been shown to become less soluble like the phosphate ion as the pH is reduced in clay suspensions (4). This is in contrast with the other minor elements which are all more available at acidic pH levels.

The content of molybdenum in organic matter appears to vary widely. Since soil organic matter decomposes slowly this may be one of the best molybdenum storehouses in the soil.

The exchangeable molybdate ion can be made readily available by liming. Robinson and his co-workers (8) increased the molybdenum uptake of legumes from six to eleven fold by liming the soil.

---

1. Journal paper no. 1679 Purdue University Agricultural Experiment Station. Contribution from the Department of Agronomy. Financial assistance from the Climax Molybdenum Co. is gratefully acknowledged.

The effect of liming on molybdenum uptake depends on the amount of unavailable molybdenum in the soil.

Anderson (2) points out that the small amount of molybdenum which clover plants obtain from molybdenum deficient soils is sufficient for metabolism (nitrate reduction) of the host plant. This indicates that any plant responses to molybdenum usually arise from some beneficial effects on the symbiotic nitrogen fixation mechanism. He has shown that smaller molybdenum responses occur on these soils when adequate nitrogen is present. Thus a primary function of molybdenum to leguminous plants is its aid in supplying nitrogen to the host plant.

The objective of this work was to determine if there are areas in Indiana where molybdenum deficiencies are a limiting factor in crop production.

Where should molybdenum responses be expected?

1. Acid soils tend to tie up molybdenum and may be low.
2. In sandy soils some of the molybdate salt may be lost by leaching.
3. Soils which have been heavily cropped, especially in areas where hay is sold off the farm, would be low because of crop removals.

Foy and Barber (7) reported molybdenum deficiencies in nine of the eighteen soil types studied in the greenhouse in 1956. Alfalfa was grown on these soils which ranged in pH from 4.8 to 7.4. An example of their results is shown in table 1. The treatments used were: no lime; low lime; 250 lbs. Ca CO_3 per acre and lime according to soil test. Molybdenum treatments were 0 and 2 pounds of molybdenum per acre. A significant response was obtained on two soils (Tracy and Fox as shown in table 1) using the high rate of lime while six others approached signifi-

TABLE 1

Response of alfalfa to molybdenum on Indiana soils in the greenhouse, 1956.

Soil	Initial pH	Mo. treatment	Yield (g.dry wt./pot) 3 cuttings No lime	Low lime	High lime
Tracy loam	5.3	O	0.37	7.95	10.53
		Mo.	0.25	8.02	12.40
		Response	—0.12	+0.07	+1.87*
Crosby silt loam	5.4	O	9.02	14.73	16.81
		Mo.	12.30	15.31	18.12
		Response	+3.28*	+0.58	+1.31
Fox loam	5.4	O	2.90	11.09	11.43
		Mo.	5.18	11.69	13.39
		Response	+2.28*	+0.60	+1.96*
Gibson silt loam	5.6	O	0.07	2.63	16.18
		Mo.	0.19	7.49	14.01
		Response	+0.12	+4.86*	—2.71*

* significance at 5% level

cance. This indicates a lack of both available (soluble molybdate salt) and unavailable molybdenum in these soils. Five soils receiving no lime produced significant yield increases with molybdenum treatments indicating a lack of available molybdate at this pH level. The work of Foy and Barber in the greenhouse suggests that molybdenum deficiencies may be occurring in the field on Indiana soils.

In 1959 a greenhouse experiment was conducted using molybdenum treated seed of red clover, alfalfa and soybeans on eight acid soils. This work failed to show any significant yield increase due to molybdenum treatment. It did, however, show that the soils used contained adequate amounts of molybdenum to prevent deficiencies. Some of the results shown in table 2 indicate that the treated plants took up the added molyb-

TABLE 2

The effect of molybdenum treatment on yield and molybdenum content of red clover and alfalfa grown on a Sidell silt loam at ph 5.2.

	Hay Yield (g./pot) CUTTING				Mo. Content 1st Cutting	
	1		2			
Crop	Mo.*	—Mo.	Mo.	—Mo.	Mo.	—Mo.
Red Clover	10.66	11.80	10.40	8.68	1.9	0.9
Alfalfa	5.25	4.85	5.58	4.55	4.3	0.6

* Molybdenum was applied to the seed at the rate of ¼ ounce per acre.

denum, but failed to give yield increases. Molybdenum applied as a foliar application in the field of soybeans at four locations produced plants containing more molybdenum than the untreated plants, but no significant increase in yield was shown. This indicates once again that the soil on which the plants were grown was high enough in available molybdate. This experiment did show that molybdenum can be taken up by the soybean plant when applied as a foliar application.

In a larger survey, plant and soil samples were taken from five soybean fields on each of nineteen different soil types in Indiana. A molybdenum analysis was made of the above ground portion of the soybean plant. The results are summarized in table 3. The soil was tested for pH, available phosphorus and potassium. The dry weight of ten plants at each location was determined and the maturity stage was noted.

The molybdenum content varied from 0.06 to 21 PPM. A multiple regression analysis of the data using soil pH, available phosphate, potash, color, weight of ten plants and maturity index as the independent variables and molybdenum content of the plants as the dependent variable was made. The results showed practically no correlation of any of these factors with the molybdenum content of the soybean plant.

An analysis for the total molybdenum content of some of these soils was made and the results are shown in table 3. There was little correlation between the molybdenum content of the plant and the total molybdenum content of the soil. However, the molybdenum content of the plant did

TABLE 3

The effect of soil type on the molybdenum content of the soil and the soybean plant growing on the soil.
Total molybdenum content (PPM)*

Soil Type	Plant		Soil
	Ave.	Range	
Odell silt loam	0.47	0.06–1.12	2.08
Vigo silt loam	0.57	0.10–1.19	2.48
Chalmers silty clay loam	0.60	0.42–0.67	1.52
Fincastle silt loam	0.65	0.37–0.75	
Door silt loam	0.80	0.02–1.60	
Plainfield loamy fine sand	0.83	0.42–1.08	
Newton loamy sand	0.98	0.62–1.75	
Fox silt loam	1.13	0.74–1.58	
Tracy fine sandy loam	1.24	0.44–2.42	
Alford silt loam	1.25	0.82–1.75	
Crosby silt loam	1.49	0.42–1.91	1.77
Cincinnati silt loam	1.59	1.08–2.62	
Granby fine sandy loam	1.77	0.28–4.26	1.47
Brookston silty clay loam	1.98	0.75–3.86	
Maumee sandy loam	2.42	0.15–8.82	
Hoytville silty clay loam	3.37	1.68–4.85	3.05
Nappanee silt loam	3.57	1.45–6.94	4.29
Carlisle muck	5.85	0.42–14.34	23.20
Genesee silt loam	6.39	1.55–21.25	2.56

* Plant molybdenum analyses include five samples grown on each soil. Results from soil analyses include duplicates on one to three soils. Only one Carlisle muck sample has been analyzed.

appear to be related to soil type. All five samples from one soil type such as Chalmers, were uniformly low in molybdenum while all five from a soil type such as Nappanee were uniformly high in molybdenum. In general the soils in the northwestern part of Indiana, particularly the prairie soils, appear to be low in available molybdenum while the soils in northeastern Indiana, particularly the lake-bed soils of Allen County, were high in available molybdenum. The soils in the other parts of the state ranged from low to medium. Research is being continued to develop a method for predicting where response may occur.

Literature Cited

1. Anderson, A. J. Molybdenum deficiency on a South Australian ironstone soil. J. Australian Inst. Agr. Sci. **8**: 73-75.
2. Anderson, A. J. Molybdenum deficiencies in legumes in Australia Soil Sci. **81**: 173-182. 1956.
3. Arnon, D. I. and Stout, P. R. Molybdenum as an essential element for higher plants. Pl. Phys. **14**: 599-602. 1939.
4. Barshad, I. Factors affecting the molybdenum content of pasture plants I. Nature of soil Mo., growth of plants and soil pH. Soil Sci. **71**: 297-313. 1951.

5. BORTELS, H. Molybdenum as a catalyzer in biological nitrogen fixation Arch. Mikrobiol. 1 : 333-342. 1930.

6. EVANS, H. J., PURVIS, E. R., and BEAR, F. E. Molybdenum nutrition of alfalfa. Pl. Phys. 25 : 555-565. 1950.

7. FOY, C. D. and BARBER, S. A. Molybdenum response of alfalfa on Indiana soils in the greenhouse. Proc. S. S. S. A. 23 : 36-39. 1959.

8. ROBINSON, W. O., and EDGINGTON, G., ARMIGER, W. H. and BREEN, A. V. Availability of molybdenum as influenced by liming. Soil Sci. 72 : 267-274. 1951.

9. STOUT, P. R., MEAGHER, W. R., PEARSON, G. A. and JOHNSON, C. M. Molybdenum nutrition of crop plants. Plant and Soil 3 : 51-87. 1951.

Potato Nutrition in Southwestern Indiana[1]

Gerald E. Wilcox, Purdue University

The potatoes in southwestern Indiana are produced for the potato chip market and are harvested in late July or early August. Since they are to be matured in as short a growing season as possible, their growth must be stimulated at all stages. This means that at no time should any factor, that can be controlled, be limiting. The potatoes must be grown to be of highest possible specific gravity and chipping quality.

Soil and fertilizers supply the nutrient needs of the potato plant for its growth and development. The amount of fertilizer to apply depends on level of available nutrients in the soil and the yield response that is obtained from the fertilizer application. The response is also regulated by the absence or presence of other growth limiting factors in the potato production area.

This experiment was carried out for the purpose of determining the fertilizer requirement of the potato crop on a soil of known fertility level.

Materials and Methods

This experiment was carried out on the Paul Klein farm near Vincennes, Indiana. The soil type was a Genessee sandy loam, an alluvial terrace soil underlain with gravel. Potassium levels 0, 75, 150, 225 and nitrogen levels 32, 65, 97 and 164 pounds per acre were applied broadcast in a randomized block with four replications. Three levels of P, O, 96 and 192 pounds were applied in bands at planting in a randomized block arrangement with two replications.

Kennebac potatoes were planted 9 inches apart in the row on March 24, 1959 and April 6, 1960. The individual plots were 12 feet wide and 36 feet long. Four rows were planted on each plot and 26 feet of the two center rows were harvested for yield and tuber sampling.

The initial soil test values averaged 70 pounds per acre for phosphorus and 161 pounds per acre for potassium as determined by the Purdue Soil Testing Laboratory. In the laboratory, available phosphorus and potassium are extracted by shaking 5 g. of soil with 15 ml. of 0.75 N. HCl on a shaker 2 minutes. The values are expressed in terms of pounds P_2O_5 and K_2O per 2 million pounds soil. The soil pH was 6.1.

Plant samples were collected as recently matured leaves on ten plants in the two center rows of each plot. In 1959, the sample date was May 26 at the bud stage. In 1960, samples were collected June 1 at bud stage when tubers were just beginning to set and June 15 when the tubers were developing rapidly. The samples were dried at 70° C. in a forced air oven and ground to pass a 20 mesh sieve. The tissue was analyzed for P, Ca, Mg and K according to the methods described by Jackson (1).

The potatoes were harvested on July 26, 1950 and July 25, 1960. Four tubers from each treatment were chipped two days after harvest at the Chesty Potato Chip factory in Terre Haute, Indiana. The vat

1. Journal Paper No. 1680 Purdue University Agriculture Experiment Station, Lafayette, Indiana.

temperature was 325° F. The chip samples were prepared for color determination by grinding in a Waring blender 20 g. chips and 100 ml. H_2O. The slurry was poured into a cell and read on a Hunter color-difference meter that was standardized against a white standard.

Results

Nitrogen effect: The nitrogen test results were obtained from the 1959 crop only. Growth of the potatoes in the spring of 1959 was vigorous and by May 26 the vine growth on the high nitrogen rates nearly covered the middles of the rows. Response to nitrogen could be observed by the amount of vine growth and the color of the vines. The vines on the plots that had received only 32 pounds of nitrogen were light green and had less growth than that on the plots that received the higher rates. In figure 1 the open middle of the row of the low nitrogen treatment illustrated

Figure 1. Potato vine growth influenced by nitrogen treatment. Open middles of rows in center of picture result when only 32 pounds of N applied at planting as compared to closed middles in forefront and rear of same rows from effect of 96 pounds per acre of N.

the relative amount of growth obtained. However, even though color and growth response was obtained to nitrogen there was no measureable effect on tuber yield or tuber and chip quality.

Potassium effect: In 1959, no vine growth or yield responses to potassium fertilization were apparent. However, in 1960 severe potassium deficiency on the vines was developed at the 0 potassium rate. The leaves showed an interveinal bronzing over much of the vine and the entire growth was only about two-thirds that obtained at the 75 pound rate. The potassium in the most recent mature leaves at the June 1 sample dates, table 1, was increased from 2.14% to 4.26% by the application of 225

Table 1. Potato recently matured leaf composition at two sample dates from various K fertilizer rates. 1960.

Treatment *	Composition							
Rate K_2O Application	P		K		Ca		Mg	
	6/1	6/15	6/1	6/15	6/1	6/15	6/1	6/15
Lbs./A				%				
0	.33	.23	2.14	1.8	1.21	2.05	.48	.78
75	.31	.21	2.75	2.3	1.08	1.94	.42	.63
150	.32	.18	3.23	2.3	.90	1.77	.37	.52
225	.32	.18	4.26	3.0	.94	1.75	.37	.50
LSD 5% level	NS	.03	0.74	0.36	0.21	0.24	0.045	0.09

* All plots received 44-192-0 in bands at planting and 66 pounds per acre of N broadcast preplant.

pounds of K_2O and on June 15 the K composition was changed from 1.8% at the zero rate to 3.0% at the 225 pound rate. The composition was increased in rather uniform amounts by the 75 pound increments of K_2O fertilizer applied. As the rate of potassium fertilizer was increased the Ca and Mg in the tissue was decreased. At the June 15 sample date, P in the tissue was decreased by the higher rates of K. This could have been due to anion competition as a result of the anion carrier in the K fertilizer. The yield of tubers, table 2, was increased from 245 cwt. to 310 cwt.

Table 2. Potato yield, specific gravity and chip color from potassium fertilization.

Treatment *	Yield		Specific Gravity		Chip Color White L=85.3	
Rate K_2O Applied	1959	1960	1959	1960	1959	1960
Lbs/A	Cwt/A				L	
0	225	245	1.090	1.074	60.4	52.1
75	227	280	91	74	63.3	61.5
150	244	299	90	73	61.1	63.7
225	224	310	88	74	63.3	67.1
LSD 10% level	NS	24.3	NS	NS		

* All plots received 44-192-0 in bands at planting and 66 pounds per acre of N broadcast preplant.

per acres in 1960 over the 0-225 pound K range tested. The response to K was highest for the first 75 pound increment and fell off at the higher rates. Over the range of K rates tested there was no influence on specific gravity of the tubers. In 1960, the potatoes from the zero potassium plots produced very inferior chips. The color of the chips was much darker than those from tubers grown on the plots that received higher K fertilizer rates. An L reading of above 60 is a very acceptable chip color. The read-

ing of 52.1 for the chips from the zero K treatment represents a dark brown, burnt-looking chip.

The soil from the respective plots was sampled in the fall of 1960 to determine the influence of the potassium treatments on the amount of exchangeable K_2O in the soil after two crops of potatoes have been grown. It was found that the exchangeable K_2O level was 102 pounds per acre on the zero potassium plots and 138, 140 and 158 pounds per acre respectively for the 75, 150 and 225 pound K_2O rates. Thus, at this sampling date an annual application of 225 pounds of K_2O was required to maintain the K level in the soil.

Phosphorus effects: In the plant, the effect of P fertilization showed up mainly as an increased amount of P in the tissue, table 3. The P

Table 3. Potato recently matured leaf composition at two sample dates from various P fertilizer rates. 1960.

Treatment *	Composition							
Rate P_2O_5 Application	P		K		Ca		Mg	
	6/1	6/15	6/1	6/15	6/1	6/15	6/1	6/15
Lbs./A				%				
0	.20	.17	2.6	2.6	.87	1.40	.32	.43
96	.26	.18	3.2	2.6	.82	1.54	.32	.44
192	.30	.20	2.6	1.8	.97	1.63	.39	.51
LSD 5% level	.05	.03	NS	0.5	NS	NS	.06	NS

* P applied in bands at planting along with 44 pounds of N. In addition all plots received 180 pounds per acre K_2O broadcast preplant and 66 pounds of N sidedressed.

composition was increased most at the early sampling date. The application of P increased the tissue composition from .198 at the zero rate to .300 at the 192 pound rate at the June 1 sample date and from .173 to .200 at the June 15 sample date.

The potato yield, table 4, was increased from 244 cwt. to 319 cwt. per acre by the first 96 pound P_2O_5 increment and from 319 cwt. to 348 cwt.

Table 4. Yield and specific gravity of tubers from various phosphorus treatments.

Treatment * Rate P_2O_5 Applied	Yield	Specific Gravity
	Cwt.	
0	244	1.074
96	319	1.076
192	348	1.078
LSD 10% level	32.6	.003

* P applied in bands at planting along with 44 pounds of N. In addition all plots received 180 pounds per acre K_2O broadcast preplant and 66 pounds of N sidedressed.

per acre by the second 96 pound P_2O_5 increment. The specific gravity of the tubers was increased significantly by the P fertilization, from 1.074 at the zero rate to 1.078 at the 192 pound P_2O_5 rate.

Discussion

The lack of yield response in 1959 to applications of nitrogen, even though vine growth response was observed, and potassium may have been due to shortage of water. During the period of rapid tuber development in June most of the water had to be supplied through irrigation which could not keep up with the demand. Thus, the yield ceiling in 1959 was approximately 240 cwt. per acre and at this point nutrients were not limiting.

In 1960, the level of exchangeable potassium on the O K plot had been reduced by the previous crop to a point that it was very limiting to potato growth and yield. The reduction of exchangeable K in the acre plow layer after two years of production was about 60 pounds of K. A total application of 450 pounds per acre K_2O was necessary to maintain the 160 pounds per acre plow layer level of exchangeable K under potato production practices in this area.

The detrimental effect of potassium deficiency on chip color was very significant and when potatoes are produced solely for chip production it is very important that the potassium nutrition be optimum.

The yield response to P fertilization was equal to or greater than for K. Also the specific gravity of the tubers was higher at the highest P rate than at the deficient level of P. Apparently, when phosphorus is limiting for plant growth the rate of development of the tubers is delayed so that at harvest they contain less dry matter than tubers developed under more optimum fertility conditions.

Summary

Kennebac potatoes grown on a Genessee sandy loam soil that contained 161 pounds exchangeable K_2O per acre did not respond to potassium fertilization in 1959. Two years of protato production decreased the level of exchangeable potassium in the soil to about 100 pounds per acre. Potatoes responded to potassium fertilization the second year when the yield was increased from 245 to 310 cwt. per acre by the application of 225 pounds K_2O. Potato chips from the zero K plots were dark brown and of inferior quality. The highest quality potatoes were produced at the higher fertilizer rates.

Nitrogen rates over the range of 32 to 164 pounds per acre did not affect either the yield or the quality of the potatoes.

The soil contained 80 pounds available P_2O_5 per acre and yield was increased from 244 cwt. to 348 cwt. per acre by the addition of 192 pounds P_2O_5 per acre.

Literature Cited

1. Jackson, M. L. 1958. Soil Chemical Aanalysis. Prentice-Hall, Inc.

Statistical Evaluation of the Analytical Techniques Employed in the Purdue Soil Analysis Laboratory[1]

A. F. GOHLKE and M. F. BAUMGARDNER

Considerable research has been conducted to determine the best quantitative methods for determining the nutrient elements available in soils for plant growth. To the authors' knowledge, no work has been reported, in which the routine analytical techniques were investigated for a possible source of variation.

Even when the most accurate chemical methods are used to determine the nutrient elements, variations between duplicate analyses exist. Therefore, this work was undertaken to determine the source of variation in pH, phosphorus and potassium determinations due to the analytical techniques used by this laboratory in the routine analysis of soil samples.

This work does not attempt to explain the factors underlying the variations.

The results of triplicate analyses of 4 randomly selected soil samples are presented in table 1, to illustrate the variations which have been found to exist in the laboratory routine.

Table 1. Results of Triplicate Analysis of 4 Randomly Selected Soil Samples

Sample No.	pH			lbs. P_2O_5/acre			lbs. K_2O/acre		
33,356	5.9	5.8	5.9	420	400	400	145	125	125
33,361	5.9	6.1	5.8	280	260	240	125	145	125
33,371	7.2	7.0	7.1	850	900	900	90	125	110
33,381	5.6	5.6	5.8	220	200	200	70	70	90

Even though there are considerable variations in certain anlyses, these variations are seldom of the magnitude which would influence the type and amount of fertilizer to be applied based on these soil test results. Yet these variations are present and this source should be located so that closer duplication can be achieved.

Experiment 1

Soil samples are received at the laboratory in various physical conditions. They may be received wet or dry, pulverized or hard and cloddy. The physical conditions in which they are received influence some of these variations.

After the soil sample has been received at the laboratory, it is dried, crushed in a double roller type crusher and sieved through an 8 mesh sieve. All soil passing through the sieve is retained and portions are analyzed for phosphorus, potassium and pH determination. All soil

1. Journal Paper Number 1678, Purdue University Agricultural Experiment Station, Lafayette, Indiana. Contribution from the Department of Agronomy.

remaining on the sieve is discarded. The percentage of soil sample passing through the 8 mesh sieve ranged from 35 to 100 percent with the average being near 50% of the original sample.

Therefore, this experiment was conducted to determine if the coarse discard fraction differed from the finer retained fraction.

Twenty-eight consecutive soil samples were crushed, both the fine fraction passing the 8 mesh sieve and the coarse fraction retained on the sieve were retained and further crushed separately to pass a 20 mesh sieve. To determine the variations in pH between the retained and the discarded fraction, a 1:1 soil water suspension and a glass electrode was used. Each analysis was replicated five times.

A significant difference[2] between the fractions was found on 5 of the 28 soils, and a highly significant difference[3] on 4 of the 28 samples. These differences between fractions ranged from 0 to .4 pH units, with the discard fraction always having either an equal pH or a higher pH than the retained fraction.

Phosphorus content was determined colorimetrically (1) on each of the fractions of the 28 soil samples. Highly significant differences between the fractions were found in 14 and significant differences in 2 of the 28 samples. The discarded fraction had a higher phosphorus content in 9 of the 16 samples which showed significant differences between fractions.

Of the 28 soil samples, four had highly significant differences between fractions in the potassium content (1) and 2 differed significantly. In 5 of the 6 soils differing significantly in potassium, the higher potassium content was associated with the discarded fraction.

This experiment indicates rather conclusively that the presently discarded fraction is of significant importance, and the entire soil sample should be crushed and analyzed, especially since the discarded fraction frequently represents 50 percent of the original sample.

Experiment 2

After the soil sample is crushed, the fraction passing through the 8 mesh sieve is analyzed for phosphorus and potassium. To remove these nutrients from the soil, a 5 ml. volume measuring spoon of soil is added to an extraction bottle and the extracting reagent (1) is added simultaneously to a tray containing 12 bottles with their samples. These are then shaken for 2 minutes, filtered and each determination is made on a 2 ml. aliquot of the soil extract.

Some variations in the phosphorus and potassium content are probably due to variations in taking the 5 ml. volume of soil for extraction. The variation between technicians was investigated by sieving a Chalmers silt loam soil through a 60 mesh sieve and having each technician sample the soil 12 times in each technician's normal procedure. Phosphorus and potassium were then determined in the routine procedure to determine the amount of variation. A significant difference was found to exist between technicians.

---

2. Significant difference signifies significance at the 5% level.
3. Highly significant difference signifies significance at the 1% level.

Experiment 3

In an attempt to learn why the difference between technicians found in experiment 2 might exist, this experiment was initiated to investigate sampling techniques of the 5 ml. soil portion. This experiment was carried out by only one technician to remove variation between technicians as a variable. The following sampling techniques were used:

1. Technique normally employed by the technician.
2. Dip the sampling spoon into the soil, and level off the excess soil with a spatula.
3. Dip the sampling spoon into the soil, tap the handle of the spoon once on the handle with the edge of the spatula to compact the soil and then level-off the excess soil with the spatula.
4. Same technique as 3, except handle was tapped three times instead of once.

Each sampling technique was replicated 12 times on the soil used in experiment 2. Phosphorus was determined by the routine procedure to determine the variation. A highly significant difference due to sampling methods was found. The average phosphorus content, ranged between the highest and lowest values and the least significant differences at 5 percent, are shown in Table 2 for each technique.

Table 2. Average Phosphorus Content, Range and LSD at 5% for Sampling Techniques

	Sampling Technique			
	1	2	3	4
Ave. P_2O_2/acre	274.2	281.0	286.0	297.6
Range–lbs./acre	40	48	36	32
LSD at 5% = 8.92 lbs. P_2O_5/acre				

Since the range for technique 4 was the least, it was used in the remainder of the study.

Experiment 4

The particle size of the soil sample might influence the amount of soil which a sampling spoon might hold, which in turn might influence the phosphorus or potassium content.

To study this problem, a Chalmers silt loam soil was dry fractionated into 7 size classes: 8-20 mesh, 20-40, 40-60, 60-80, 80-100, 100-200, and finer than 200 mesh. The Chalmers soil was selected because it is a prairie soil, high in organic matter and therefore has very stable dry aggregates, which do not crush easily. A 5 ml. volume sample was taken from each fraction, weighed and analyzed for phosphorus and potassium. These were replicated 5 times.

The average sample weight, average phosphorus and potassium content are presented in Table 3. Differences in weight, phosphorus, and potassium content were all highly significant.

Table 3. Average Weight, Phosphorus and Potassium Content for Each Size Fraction

Weight of Sample	Fraction Size Classes (sieve mesh sizes) 8-20	20-40	40-60	60-80	80-100	100 to 200	Less than 200	5% LSD
grams/5 ml.	4.1758	4.2972	4.4614	4.5049	4.4301	4.4199	4.7835	.0717
#P_2O_5/acre	212.8	237.4	240.4	259.8	264.6	289.8	295.6	18.00
#K_2O/acre	119.4	132.2	136.6	132.4	140.6	146.2	145.0	5.57

Table 3 shows that the average weight, phosphorus and potassium content were dependent on particle size.

To determine if the phosphorus and potassium content were associated with the change in sample weight, or if a real difference due to fraction existed, all phosphorus and potassium contents were adjusted to a 5 gram sample weight.

The phosphorus and potassium contents when adjusted to 5 gram sample weights are shown in table 4.

Table 4. Average Phosphorus and Potassium Content When Values Were Adjusted to 5 Gram Sample for Each Fraction

	Fraction Size Classes (sieve mesh sizes) 8-20	20-40	40-60	60-80	80-100	100 to 200	Less than 200	5% LSD
#P_2O_5/acre	254.4	276.4	269.2	288.4	298.6	327.8	309.8	21.7
#K_2O/acre	143.0	154.6	153.2	146.8	158.8	165.4	145.6	5.3

The phosphorus and potassium contents were highly significant when they were adjusted to a 5 gram sample.

Since both phosphorus and potassium content appear to be dependent on the fraction size, even though the sample weight is equal, regressions and correlations were calculated for both phosphorus and potassium on fraction size.

The phosphorus content followed a linear regression on fraction size, with $b = .327$ and had a correlation coefficient, $r = .873$. The regression and correlation were both significant. Potassium content and fraction size had a correlation coefficient, $r = .217$, which is not significant.

The data in table 4 shows that the fraction size which is sampled was very important in both phosphorus and potassium analysis. In coarse crushed samples, many fine particles could settle to the bottom of the sample box. This would leave the coarse fraction near the surface. These would have a greater chance of being included in the volume of soil being analyzed, and might result in large variations in the test results, especially phosphorus.

Experiment 5

After the 5 ml. volume of soil has been sampled, extracting reagent is added, shaken and filtered. A 2 ml. aliquot of the resulting soil extract

is pipetted into test tubes for phosphorus and potassium determination. Since an automatic pipette is used to remove the aliquot, it is not rinsed between samples. Therefore, this experiment was conducted to determine the amount of phosphorus carried over from one sample to the next. The phosphorus carry-over was determined by rinsing the pipette with 2 ml. of distilled water and determining the phosphorus in the distilled water. All phosphorus found in the distilled water was being carried over in the pipette to the next sample.

The amount of phosphorus carried-over in the pipette when pipetting a sample with a known phosphorus concentration is shown in figure 1. This figure shows the amount of carry-over to be a significant source of variation in phosphorus analyses.

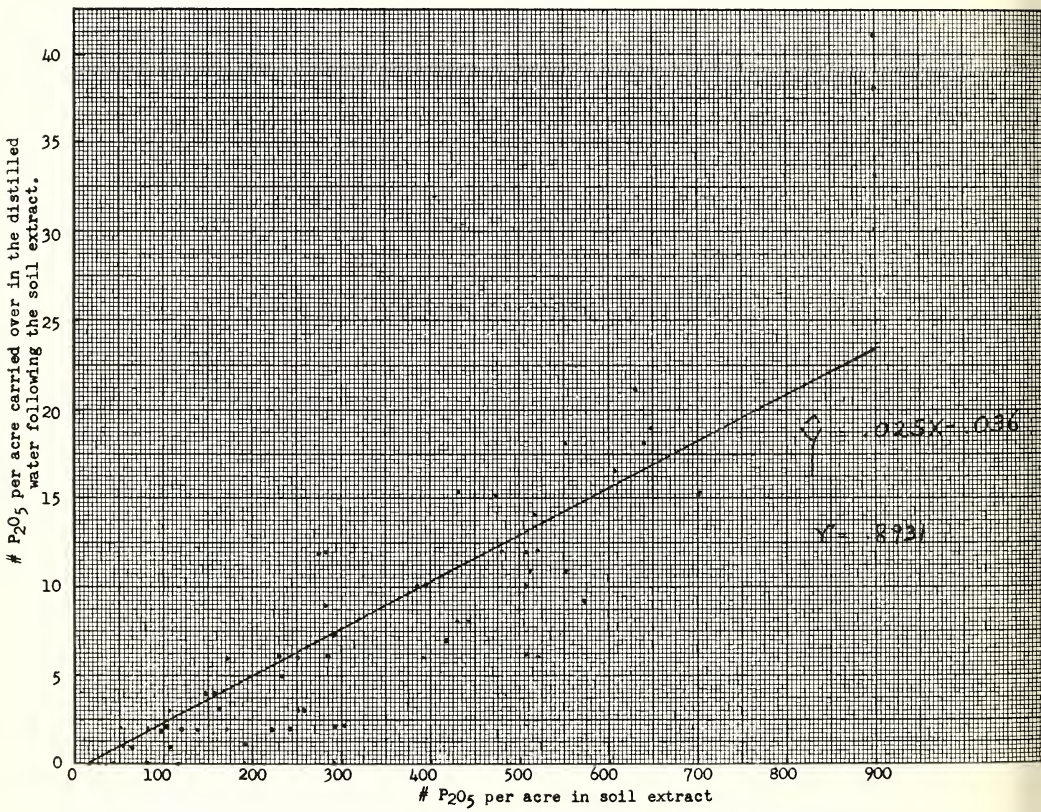


Fig. 1. Pounds per acre of P_2O_5 carried over in the transfer pipette when pipetting a soil sample extract of known P_2O_5 content.

Experiment 6

As table 1 shows, the pH values of the soils varied only slightly between duplications. It was thought that since the water is added to the soil and is allowed to stand for a period of time before making the determinations, this might be a source of variation.

The pH was determined with a glass electrode on several soils at various intervals between 5 minutes to 8 hours after adding the water to the soil. No difference in pH was found due to allowing the water to be in contact with the soil for as long as 8 hours.

Summary

This study has indicated that numerous factors present in the routine now used are sources of variation between duplicates of the same soil sample. Numerous additional factors remain to be investigated. When all the factors causing variation have been studied and corrected, closer duplication should result.

Literature Cited

1. Spain, J. M. and White, J. L. Procedure for the Determination of Phosphorus and Potassium Soil Testing. Unpublished date, Purdue University. March 1960.

The Response of Corn Roots to High Nutrient Concentrations within a Single Root Culture Cell[1]

B. T. KANG and A. J. OHLROGGE, Purdue University

Introduction

In recent years many studies have been made concerning root development around a fertilizer band. The chemical and physical reactions taking place within or adjacent to the band have also been studied. However, little or no attention has been given to the behavior of the few roots which actually strike or penetrate the band where unfavorable conditions of high salt concentrations probably exist.

Results of a study by Lindsay and Stephenson (3) indicate, that the solution leaving a band of monocalcium phosphate monohydrate is highly concentrated and acidic in nature. This solution is believed to have a composition either of a meta-stable triple-point solution with a P content of 3.98 M, a Ca content of 1.44 M, and a pH of 1.48 or that of a triple-point solution with a P content of 4.495 M, a Ca content of 1.34 M, and a pH of 1.01.

From greenhouse experiments with partial root system Duncan and Ohlrogge (1) concluded that the small roots of young corn plants around a fertilizer band are little affected by the salt concentration that might normally exist near the band. Lehr and Brown (2), using several sources of phosphate fertilizers in an experiment with ryegrass and Sudangrass found that there was a consistent development of the roots within the fertilizer sites which included the central region composed essentially of crystalline calcium phosphates. Their petrographic studies have shown the presence of calcium phosphate crystals firmly bound to the root hairs.

Considering the high salt concentration of the solution around the band, it is a striking observation that the roots which come in contact with the fertilizer band survive and function in nutrient absorption.

There are some indications that partial root systems of corn do tolerate osmotic concentrations in soil and vermiculite which are well above the upper limit of tolerance for the whole root system (1). Just as the nutrient uptake from a fertilizer band is in part dependent upon the osmotic properties of the soil and on the solution leaving the band, a better understanding is needed of the reactions of partial root systems. This is particularly true where high nutrient concentrations are involved. Some preliminary results of greenhouse experiments conducted in this area are presented.

Materials and Methods

Greenhouse experiments were set up to study the response of a portion of a single corn root to different phosphorus concentrations. Small cells

1. Journal Paper No. 1682, Purdue University Agricultural Experiment Station, Lafayette, Indiana. Contribution from the Department of Agronomy. Part of a thesis submitted by the senior author in partial fulfillment of the requirements for the Ph. D. degree.

were constructed for this purpose from 0.006 inch thick Mylar plastic. Each cell consisted of a small cylinder having a diameter and a length of 1.9 and 1.7 inches, respectively. At the bottom and top it was sealed with multiwax[2] impregnated cheese cloth. The top cover was made sufficiently thick so that roots did not penetrate through it. In the center of the top cover a piece of glass tube with a diameter of 0.15 inch and a length of 0.6 inch was inserted for about 0.4 inch inside the cell and sealed in place with parafin. The bottom of this 0.6 inch tube was covered with multiwax impregnated cheese cloth. Thus the cell constituted a closed system preventing moisture exchange with the surrounding medium. By varying the size and the dimension of the cell, the volume of the cell could be changed as well as the length of the root that is exposed to the medium inside the cell. In this experiment, the length of the primary root exposed to the cell medium was approximately 1.3 inches.

Expanded vermiculite (Terralite) was used as the medium inside the cell. This material was chosen because of its high porosity which facilitated straight growth of the root exposed to the medium. On the other hand, this material has the disadvantage of possible reactions with the added fertilizer.

The source of phosphorus was triple-point solution, prepared according to the procedure given by Lindsay and Stephenson (4).

Two series of treatments were used, one with 1/100 M ammonium nitrate and the other without. Each series consisted of 11 treatments with the following dilutions of a triple-point solution: 1.0, 0.5, 0.2, 0.1, 0.09, 0.08, 0.06, 0.05, 0.04, 0.02 and distilled water. The treatments were numbered from 1 to 11 respectively. Six grams of vermiculite were placed in each cell and then saturated with 19 cc of the above indicated solutions.

The experiment was set up in a completely random design with four replications. Tin cans having a diameter of approximately 6 inches and a depth of 7 inches were used. These cans were lined with polyethlene plastic bag and filled with water-soaked vermiculite. Two cells were then placed in each tin can at a depth of about 2 inches. Three-day old corn seedlings of the single cross WF9 x 38-11, which had primary roots with a length of about 1 inch were planted with the first quarter of an inch of the primary root tip trained into the glass tube of the cell, and vermiculite was placed on top of the cell and around the seedling. Through each cell only a single root was trained. This root was able to grow through the wax impregnated cheese cloth without apparently "breaking the seal" of the system. Only seedlings with healthy primary roots which were growing straight downward were used.

The remainder of the root system outside the cell was fertilized with a total of 300 cc Hoagland solution minus phosphorus.

Twenty eight days after transplanting, the tops were removed and the roots washed. The roots which grew within the cells were harvested separately. The experimental results are presented as root and shoot weights, phosphorus content and reports of visual observations.

---

2. Multiwax W-835, a crystalline wax produced by The Sonneborn Chemical and Refining Corporation, Chicago.

Results and Discussion

Comparing both series (with and without nitrogen), there were no differences in the number of plant roots per treatment that grew into and through the cell. In treatments 7 to 11 of both series, the primary roots in all four replicates grew through the bottom wax layer of the cell with the exception of treatment 11 of the nitrogen series. In the last mentioned treatment, the primary roots in three of the four replicates were killed. Probably toxic concentrations of NH_4 arising from ammonium nitrate as a result of high temperature and other prevailing conditions could cause this effect.

In treatments 4, 5, and 6 of both series, the roots penetrated and developed inside the cells. Yet, because of their limited growth they did not grow out through the bottom of the cells. With the nitrogen treatments the portion of the primary roots that developed inside the cell were from ½ to 1½ inches long. Though the roots in treatment number 6 reached a length of 1½ inches, it appeared that they did not have the ability to penetrate through the lower wax layer of the cell. In the no nitrogen series, the primary roots grew to a length of approximately ½ to 1 inch inside the cell.

In treatments 1, 2, and 3 of both series, the primary root tip died. Short healthy appearing lateral roots were observed on the primary root at about 3 mm from the tip by use of 20 power binoculars. These lateral roots, as well as the portion of the primary root behind the tip, were densely covered with root hairs on which salt crystals were observed. Apparently the rapid growing primary root tip was killed as a result of contact with the concentrated medium. The lateral roots which developed later, could tolerate the prevailing conditions probably through a process of adjustment, which may be associated with a slower growth rate.

The nitrogen series showed much more root development inside the cell (Figure 1.). They also had a higher order of root branching. Considering treatments 7 to 10 in both series, the roots in the nitrogen series showed the presence of third- to fourth-order of branching while in the no nitrogen series showed only first order of branching except for treatment 10 which showed second order of branching. The blank treatment (treatment 11) without nitrogen showed a first order of branching and with nitrogen it attained a second order of branching. This is in accordance with the observations of Duncan and Ohlrogge (1).

At lower concentrations of the triple-point solution there was a greater degree of root development when nitrogen was applied. However, there is no apparent explanation for the relatively greater root growth in treatment 7 as compared with treatments 8 and 9 in the nitrogen series. The difference in root growth between treatment 6 and 7 of the nitrogen series and 9 and 10 of the no nitrogen series is distinct and striking. The role of ammonium nitrate in increasing the tolerance of the primary root for lower triple-point dilutions, is not understood and is being studied. It should be mentioned here that the aeration inside the cell might have considerable influence on the root development within the cell.

From a comparison of the total dry weights of the plants (minus the portion of the roots which grew inside the cell) it is apparent that

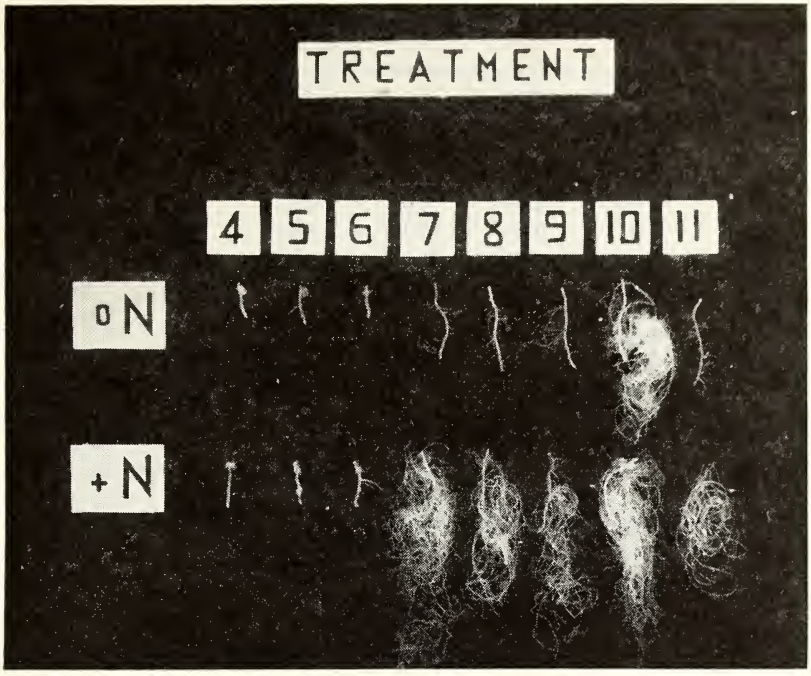


Figure 1

Table 1. Dry weight of root, shoot and total expressed in grams per plant.

Series	Plant part	Treatment Number 1	2	3	4	5	6	7	8	9	10	11
0 N	Shoot	0.51	0.44	0.44	0.63	0.50	0.61	0.68	0.64	0.63	0.74	0.40
	Root	0.41	0.42	0.39	0.45	0.39	0.48	0.48	0.49	0.50	0.60	0.36
	Total	0.92	0.86	0.83	1.08	0.89	1.09	1.16	1.13	1.13	1.34	0.76
+ N	Shoot	0.46	0.46	0.45	0.53	0.64	0.64	0.68	0.72	0.76	0.70	0.40
	Root	0.41	0.41	0.40	0.51	0.53	0.53	0.52	0.58	0.57	0.55	0.36
	Total	0.87	0.87	0.85	1.04	1.17	1.17	1.20	1.30	1.33	1.25	0.76

applied phosphorus enhanced plant growth. Though root development within the cell was limited under the conditions of treatments 1, 2, and 3, there was a marked yield response to phosphorus.

In the case of treatments 6 through 9, there was a marked yield response to nitrogen. This response was greatest for treatment 9. In the no nitrogen series, the maximum response was shown in treatment 10.

The phosphrous content of roots and shoots seemed to be correlated with the extent of root development within the cells. The greater the amount of root development the higher the phosphorus content. Phosphorus content for all treatments exceeded that of the blank (Table 2.).

Table 2. The phosphorus concentration in shoot and roots, and the total amount of phosphorus per plant.

Treatment Number	+ N			O N		
	% P		Total P in mg/plant	% P		Total P in mg/plant
	Shoot	Root		Shoot	Root	
1.	0.05	0.04	0.79	0.05	0.02	0.68
2.	0.04	0.05	0.69	0.05	0.02	0.60
3.	0.06	0.03	0.98	0.06	0.02	0.69
4.	0.07	0.04	1.14	0.06	0.02	0.92
5.	0.08	0.04	1.46	0.05	0.02	0.66
6.	0.08	0.03	1.34	0.06	0.02	0.92
7.	0.50	0.15	8.30	0.08	0.02	1.27
8.	0.33	0.11	6.02	0.10	0.03	1.58
9.	0.26	0.09	5.07	0.11	0.04	1.77
10.	0.37	0.14	6.71	0.25	0.07	4.74
11.	0.04	0.03	0.54	0.05	0.02	0.54

This uptake was quite striking even where there was little root development (treatments 1, 2, and 3). Perhaps passive absorption of phosphorus by the damaged primary root tip was involved here. Likewise, contact exchange between root hairs and salt crystals could have been involved.

The higher phosphorus uptake at higher phosphorus concentrations in the presence of nitrogen indicates that nitrogen increased the tolerance of roots to this environment. Thus, it appears that not only the total salt concentration but also complementary nutrients effect root growth and function. Treatments 7, 8, and 10 of the nitrogen series showed a P concentration of above 0.3 percent which represents luxury consumption. There seems to be no logical explanation for the phosphorus content maximum under the conditions of treatment 7 where nitrogen was applied.

Summary and Conclusions

A growth cell for single corn root was devised to study the response of single corn roots to different nutrient concentrations.

The primary roots of young corn plants showed little or no root development in a vermiculite media containing a phosphorus solution approaching the concentration of a triple-point solution.

The presence of small amounts of ammonium nitrate mixed with triple-point solution, increased the tolerance of the primary corn root to lower dilutions of the triple-point solution.

A small portion of the primary corn root in contact with the appropriate media can supply the phosphorus needed by the young corn plant.

Literature Cited

1. DUNCAN, W. G., and OHLROGGE, A. J. 1958. Principles of nutrient uptake from fertilizer bands. II. Root development in the band. Agron. Journ. 50: 605-608.

2. LEHR, J. R., and BROWN, W. E. 1958. Calcium phosphate fertilizers: II. A petrographic study of their alterations in soils. Soil Sci. Soc. Amer. Proc. 22: 29-32.

3. Lindsay, W. L., and Stephenson, H. F. 1959. Nature of the reactions of monocalcium phosphate monohydrate in soils : I. The solution that reacts with the soil. Soil Sci. Soc. Amer. Proc. 23 : 12-18.

4. Lindsay, W. L., and Stephenson, H. F. 1959. Nature of the reactions of monocalcium phosphate monohydrate in soils : II. Dissolution and precipitation reactions involving iron, aluminium, manganese, and calcium. Soil Sci. Soc. Amer. Proc. 23 : 18-22.

ZOOLOGY

Chairman: CARL H. KREKELER, Valparaiso University

L. E. DELANNEY, Wabash College, was elected chairman for 1961

ABSTRACTS

The Distribution of Cavernicolous Beetles in Indiana. CARL H. KREKELER, Valparaiso University.—Eight distinct species groups of the genus Pseudanophthalmus are now known from Indiana. Groups *leonae* and *powelli* are each known from only one cave. Group *barri* is known from possibly interconnected caves lying in a relatively restricted area. The remaining five groups have relatively extensive distributions. Forms of the *tenuis, eremita,* and *youngi* groups occur in caves of the Blue River, Lost River, and East Fork of the White River drainages. It is suggested that dispersal has occurred across the low divide that separates these drainages. In the case of the *shilohensis* group certain forms are found in caves separated from others by strata in which underground channels are not likely to be found; hence dispersal has probably been at or near the surface. Dispersal may well have been favored by the moist and cool climate obtaining during Pleistocene glaciation. In some cases at least dispersal occurred late in the Pleistocene, for Indiana forms of group *horni* are found in caves lying within the area of Illinoisan glaciation. The great variety of forms of Pseudanophthalmus in Indiana may be related to the fact that it is the major cave area of eastern North America lying adjacent to the terminus of a glacial ice sheet. Here conditions may have been optimal for dispersal and diversification of ancestral forms which subsequently found refuge in caves.

A Critique of Nuclear Fractionation Schemes. JAY BARTON II, Saint Joseph's College.—The elements which various schemes of fractionation have in common were examined. The following observations were discussed and supporting evidence submitted. (1) Preliminary sequestering of divalent ions is necessary for extraction of nucleoprotein complexes. (2) Sequestering is also necessary to obtain the "nuclear ribosomes" and the so-called soluble phase. (3) Lateral cross-linking of nucleoprotein complexes is much more easily ruptured than is end-to-end linking. (4) Heterogeneity in the preparations is a reflection of the variation of nuclear composition with the activity and stage of the cell. (5) Residual protein is normally bound with DNA as well as histone and RNA. The structure and role of the residual or metabolic fraction were examined.

Preliminary Studies on the Growth Rate of *Natrix sipedon*. PHILIP BAKER, JOHN R. HENDRIX, and WILLIAM B. HOPP, Indiana State Teachers College.—Sixteen young water snakes *(Natrix sipedon)* five to six weeks old were chosen from two litters and divided into four groups of four specimens each. One group had food available at all times, another group was fed once a week, another fed every two weeks, and the fourth fed at irregular intervals. After six months, the group receiving food once a week recorded the greatest increase in weight, closely followed by those

with food available at all times. On the basis of this limited sampling, it would seem that there is no advantage in feeding more frequently than once a week.

Experimental Production of Gill-lessness in Newts and Axolotls.[1] L. E. DELANNEY and R. R. NEAL, JR., Wabash College.—In inquiring into the reciprocal relationship of the blood-vascular system and gills we questioned the survival value of gills *per se* and elected to test this via the technique of Harrison (1921). Early embryonic flank ectoderm transplanted to the gill-forming area of the West Coast newt, *Taricha torosa*, in 15 cases not only permitted survival of totally gill-less animals beyond the 26 days reported by Harrison but 6 survived in excess of 42 days and at present one survives for over 5 months. For a 2 month period, at 20°C., there is only doubtful size variation between experimentals and controls; by 3 months the experimentals lag dramatically and are only about half the trunk and total length of the controls and thus below half the volume. At 4 months the larva persists with mid-larval pigment characteristics but the controls have metamorphosed. Axolotls, *Siredon mexicanum*, similarly treated, now survive in excess of one month. Since these axolotls retain gills when sexually mature, comparative studies of possible surface-volume ratios between the two kinds of salamanders will be pursued; also, the possible role of gill-lessness on the pituitary-thyroid physiological axis is discussed and will be explored.

Preliminary Observations on Homograft Reactions in Axolotls and Their Possible Genetic Implications.[1] L. E. DELANNEY, E. R. JOHNSON and G. WOODHAM, Wabash College.—Homograft rejections, only recently established for fish and anurans, with one report for newts, are supported by homograftings reported here for the axolotl, *Siredon mexicanum*. Six sets of reciprocal homografts are involved. Exchanges between black and white axolotls, 1 per week for six weeks (first set through sixth set) demonstrate vigorous hemostasis, hemorrhage, and epidermal rejection followed by dermal replacement with a range, in white homografts to black hosts, of first set degenerative changes in 5 weeks and final repair with host pigmentation in 13 weeks to only 3 weeks and 8 weeks respectively for sixth set. Black homografts on white hosts are rejected just as surely but with less dramatic hemorrhage or epidermal erosion. Two cases, 1 white, 1 black, to date have accepted contrasting skin with no alteration of the graft for over 3 months. No white axolotl receiving white skin has shown signs of rejection, suggesting isogenicity in this respect. All experiments have been with males to date since males are identified with ZZ sex chromosomes and controversy exists over the relationship of histocompatibility genes to sex chromosomes in amphibia; further experiments along these lines are in progress.

1. Supported by a research grant, RG-5619, from the U. S. Public Health Service.

Breeding Colonies of Four Species of Bats of Indiana

James B. Cope, Wilson Baker and Jack Confer, Earlham College

Introduction

In June 1958 the senior author, James B. Cope, initiated an extensive study of the bats of Indiana. Numerous Earlham students have helped with the project. Special assistance has been given by Bernard Gross, Roger Grothaus, Jay Schnell and Nixon Wilson. Russell Mumford of Purdue University has helped with field work. Special thanks goes to the National Science Foundation grant which made this study possible.

Most of the work was done during the summer, since the main objective was to locate breeding colonies of bats. The summers of 1958 and 1959 were devoted to the search for colonies throughout the state. The summer of 1960 was devoted to rechecks of colonies found previously, and new leads were checked out.

The method used in locating colonies was as follows: A sign was printed saying "Bats Wanted" in bold red letters. This was followed by finer print saying that a scientific study of bats in Indiana was being conducted; that if anyone knew of the location of colonies of bats in barns, schools, churches, other buildings, and caves, it would be appreciated if they would inform the senior author of the location. These signs were posted at places likely to attract attention; such as newspaper offices, stores, telephone poles, grain elevators, gas stations, etc. In each county the agricultural agent was contacted and informed about our study, and his help was solicited. An attempt was made to put short articles in county newspapers. Radio stations were also contacted.

By these methods a total of 275 leads were checked out during the three summers. Of these leads approximately 190 turned out to be good breeding colonies. A number of these colonies turned out to be inaccessible for banding. Many of the leads turned out to be places where they had had two or three bats in the house at one time, but where there was no indication of a breeding colony. These strays nearly always turned out to be males. Breeding colonies seldom have many adult males. It seems likely, therefore, that males establish "bachelor quarters" during the breeding season. These "bachelor quarters" contain only a few individuals. Often a male will return to the same place every evening. Evidently they have definite places to roost during the day and between feeding trips in the evening.

Our success in locating many colonies of bats was due to a number of people wanting to have their bats exterminated. This proved very helpful as it led us to contact exterminating companies for further leads. We found a number of colonies by this method. Our interest, of course, was not in exterminating bats, but we were able to give hints on how to build bats out.

Breeding Colonies

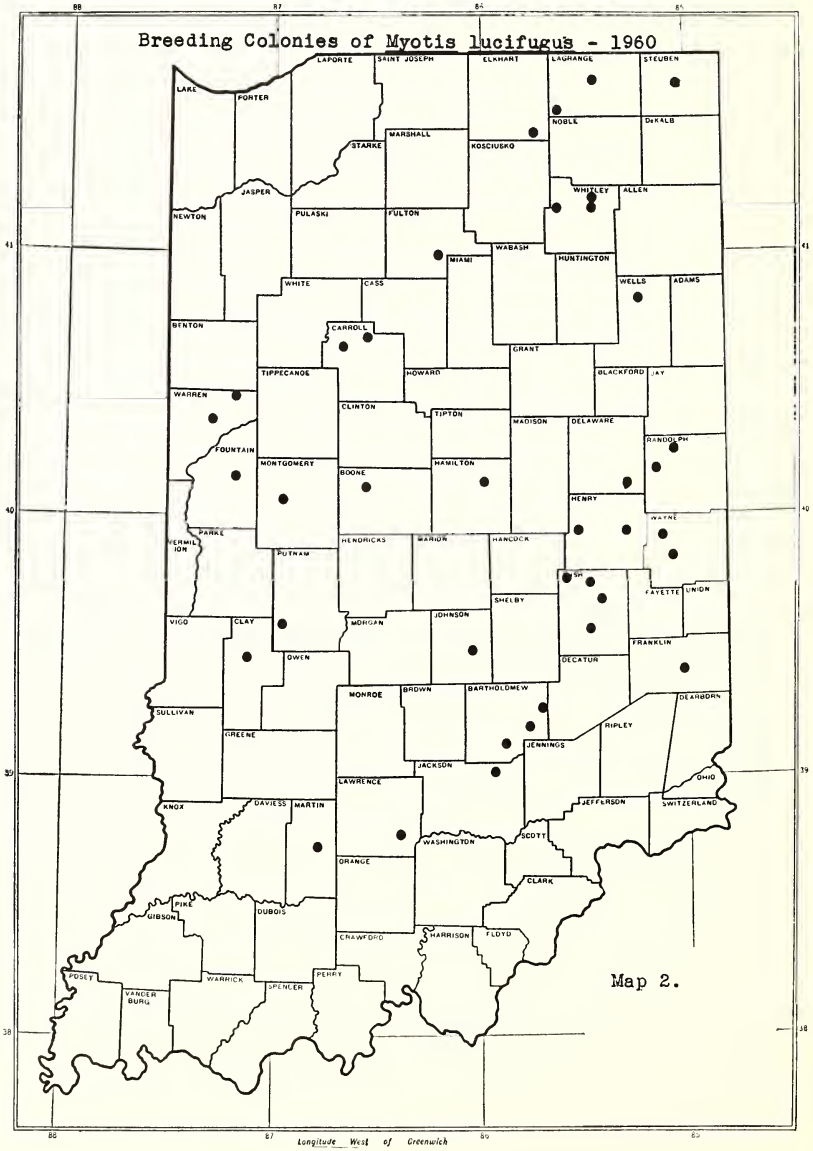
One colony of the Eastern Pipistrell, *Pipistrellus subflavus*, was found. This colony was located in Jackson County State Forest near (Map # 1) Brownstown, Indiana. On July 30, 1958, a colony of thirty

adults was found in a barn in the State Forest. It was estimated that seventy percent of the adults had young. This colony was checked again during the summer of 1959, but the bats were not there. The superintendent of the State Forest had spread axle grease along the beams where the bats had stayed.

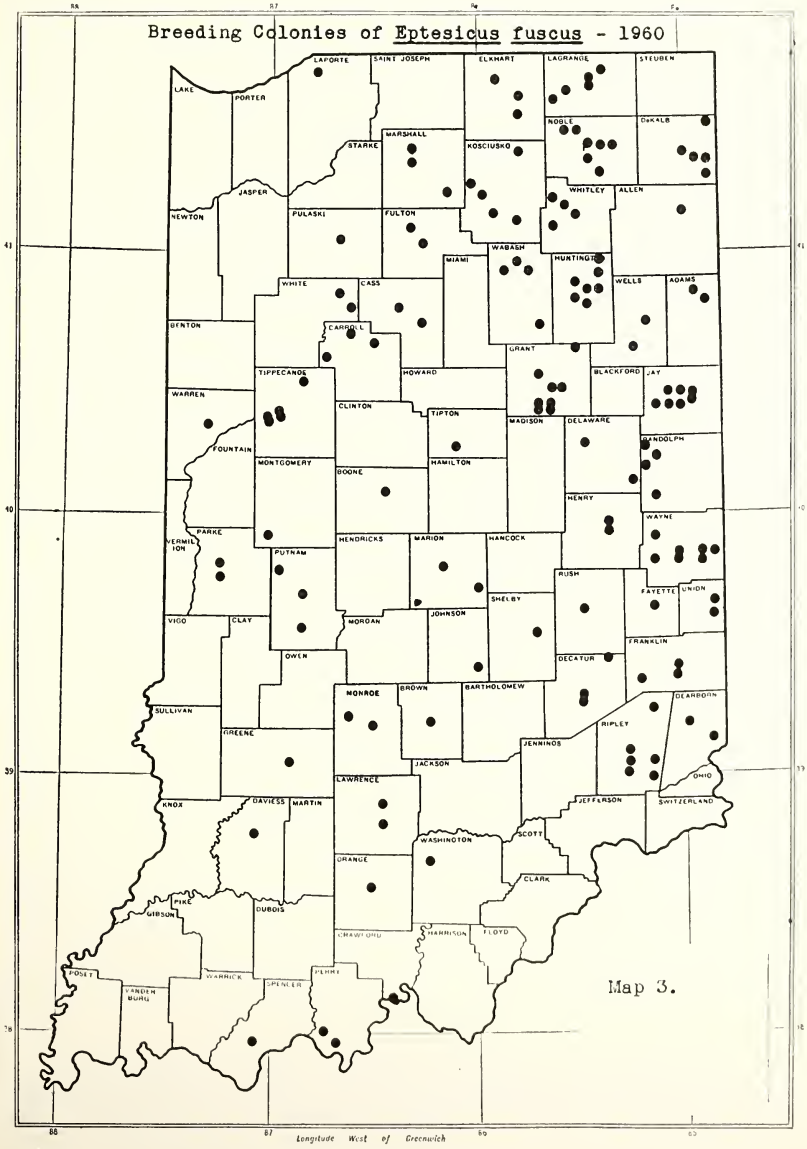
This colony was checked again during the summer of 1960. On June

14 no Pipistrells were seen in the barn but a few were seen flying around at dusk. On June 30 six adults and six to ten young were seen.

Four active colonies of the Evening Bat, *Nyctecieus humeralis*, were found. They were all in southern Indiana, in Clark, Clay, Orange and (Map #1) Washington Counties. These colonies were in rather old homes, one being over 100 years old. The total estimated population of these colonies was 460 bats. In a recent letter, Russell Mumford informed



us that the Clay County colony was no longer active. One other likely Evening Bat colony was found in White County in the northwestern part of the state. During the summer of 1959 three mummified specimens were found in the attic of a house. No live bats were seen either in 1959 or 1960. Another colony was found just over the state line in Illinois. This colony in Edgar County had approximately 75 bats.



According to our records, the Little Brown Bat, *Myotis lucifugus*, and the Big Brown Bat, *Eptesicus fuscus*, are by far the commonest colonial bats in Indiana. Forty-one colonies of the Little Brown Bat were found in 25 counties. (Map #2) This species was usually found in churches, houses and occasionally in barns. Many more individuals were found in individual colonies than any other species. One colony, for example, in Martin County, had by actual count 2,510 individuals. For the year 1960 the estimated population for *Myotis lucifugus* was 13,000 individuals.

A total of 142 colonies of the Big Brown Bat was found in 51 counties. (Map #3) The size of these colonies was much smaller than those of the Little Brown. Most had 25 to 50 adults and several had about a dozen. The largest colony had 216 individuals. Big Browns were usually found in barns but occasionally in churches and attics. Our estimated total population for this species in 1960 was 7,500.

One very interesting fact was observed in some colonies. At several locations Big Brown and Little Brown were living in the same building. Usually these were stray Big Browns living with a colony of Little Brown Bats, although sometimes the opposite situation existed. But in seven instances there were two definite breeding colonies of different species occupying the same building.

Future Work

The chief concern of future work will be intensive life history studies of breeding bats. This will include: 1. the distances that bats travel from the home roost when they are foraging at night; 2. determination of the bat's diet; 3. re-checking and banding in colonies; 4. continued search for new colonies.

A Method of Tagging Bats with Radioactive Gold-198 in Homing Experiments[1]

James B. Cope, Edward Churchwell and Keith Koontz,
Earlham College

With the use of radioisotopes, the fields of chemistry and biochemistry have been greatly enhanced. Certain types of experiments can now be performed which were not possible before the use of radioisotopes.

Radioactive isotopes are not solely confined to chemistry. These materials can also be applied advantageously to biological studies involving the movement and tracing of small animals. A number of ways have been devised to apply radioactive materials to small animals without injury to the animal or the experimentor. Stephen V. Kaye (2) describes how he used gold-198 wires inserted under the skin of Eastern harvest mice to trace their movements. We wish to describe one way in which gold-198 was used in homing experiments with bats.

In choosing an isotope, several things must be considered, as described by D. R. Griffin (1) and R. C. Pendleton (3). They say that the type of experiment will determine the kind of radiation needed. Alpha particles can not penetrate the skin and beta particles can only penetrate a few millimeters, therefore an isotope emitting either alpha or beta radiation would only increase the radiation dose to the bats without materially facilitating instrumental detection. Bats have a tendency to crawl into crevices in caves, behind rafters and beams, and brick walls three inches to two feet thick, therefore it is necessary to use an isotope emitting gamma rays with high enough energy to penetrate these objects.

When dealing with living organisms it is usually preferable to use an isotope with a short biological half-life as well as a short physical half-life. An isotope of this type would not give a bat enough radiation dose to alter its natural behavior. It is also a safety factor for the bats and for the experimentor. A short physical half-life is desirable for a number of reasons. Disposing of the waste materials is much more convenient. If expensive laboratory equipment is contaminated, a good physical washing and time will solve the problem rather than disposal. Also, if more than one experiment is to be carried out in the same colony, one would want the activity from the first experiment not to be detectable while doing a second.

Another factor to be considered is the availability of an isotope which would meet the above requirements. Gold-198 was chosen because it has a half-life of 2.7 days, a gamma energy of 0.41 million electron volts, and can be obtained very readily.

The gold came in a liquid called Aurcoloid, which is a colloidal suspension containing particles of radio-gold approximately 0.003 micron in diameter. The specific activity of this gold when prepared is from

1. The writers are indebted to William K. Stephenson for his valuable technical assistance in laboratory procedures. We also are indebted to David Telfair for his assistance with the monitoring equipment. Special thanks go to the National Science Foundation grant which made the project possible.

3 to 4 millicuries per milligram or from 20 to 40 millicuries per cubic centimeter. Five lambdas of this liquid were pipetted onto the inner surface of opened U. S. Fish and Wildlife Service bands. The isotope was applied to the inner surface of the band so a bat could not eat the isotope from the band. These bands were then placed under an infra-red light for approximately ten minutes to dry. After drying, the inner surface of the bands were painted with clear finger-nail polish. Finger-nail polish was used to keep the isotope from actually coming in contact with the bats, and because it will not crack or chip when the band is closed on the bat's wing.

As soon as the finger-nail polish had dried, the bands were numerically arranged in groups of ten and put in small pill boxes. These boxes were then put into a lead container about two inches thick in the order in which they would be taken out. The whole process of applying the isotope to the bands and drying them was done behind lead shielding. Thin polystyrene gloves were worn while working with the radioactive material in making up the bands and applying them to the bats. This prevented the gold from coming in contact with the hands.

The bats were not banded until they had been transported the desired distance away from their home colony. It was to our advantage to release the bats as they were banded. By doing this an accumulation of unshielded radiation was avoided. An accumulation of these bands would not have been potentially dangerous, but radiation exposure should be avoided as much as possible no matter how low the activity.

Bands were detected when the bats came back to the home roost with a portable Nuclear Measurements Geiger-Mueller counter with a scale ranging from 0 to .2 milliroentgens per hour. These bands could be detected a little more than a meter away after four to six days. Bats were detected through slate, tin, shingles, rafters, and brick walls with very satisfactory results. Three times during the experiments, we were able to detect radiation behind a brick wall at a distance ranging from 2 to 3 feet. One using the conventional method of banding and recapture could not possibly have seen these bats and would not have been aware of their presence. It was apparent that radiation was not detected by the sense receptors of bats, therefore their natural behavior was probably not altered because of the gold-198 tagging. This method offers another advantage in that the bats can be detected without having to catch them.

An estimation of the percentage of returns was made on the basis of the number of radioactive spots found in a building housing a colony, and the amount of activity found at each spot.

This method of detecting bats in homing experiments has some disadvantages that should not be overlooked. There is a lot of expense involved in equipping a laboratory to handle radioisotopes. The danger of radiation exposure is always present when one works with radioisotopes. Another disadvantage is encountered if the bats are released as they are banded. Sometimes it takes a period of 30 to 40 minutes to band a group of bats. When bats were detected by a Geiger counter, we did not know whether it was the first one released or the last. The greatest disadvantage which we encountered was the fact that gold-198 could be detected for such a long period of time. We had hoped to use one colony for a number

of experiments, but this was impossible because the activity from the first experiment was still detectable after four weeks. Even though 95% of the activity of gold-198 has been emitted after eleven days, the other 5% can be detected for two weeks longer.

This method has a number of disadvantages, but we feel that the advantages by far outweigh the disadvantages. Many of the experiments which we were able to do would not have been possible without the use of radioisotopes.

Literature Cited

1. GRIFFIN, D. R. 1952. Radioactive Tagging of Animals Under Natural Conditions. Ecology 33 : 329-355.
2. KAYE, STEPHEN V. Gold-198 Wires Usel to Study Movements of Small Animals. Science 131 (3403) : 824, Mar. 18, 1960.
3. PENDLETON, R. C. 1956. Uses of Marking Animals in Ecological Studies : Labeling Animals with Radioisotopes. Ecology 37 : 686-689.

Notes on Homing of Two Species of Bats, *Myotis lucifugus* and *Eptesicus fuscus*[1]

James B. Cope, Keith Koontz, and Edward Churchwell,
Earlham College

Homing experiments with bats in the United States began in 1924 when Howell and Little (3) banded and released five *Eptesicus fuscus* 20 miles from their home colonies. Since that time a number of homing experiments have been undertaken. A discussion of those prior to 1955 can be found in the work of Cockrum (1). Some of the outstanding experiments since 1955 have been carried out by Mueller and Emlen (4) who worked with cave hibernating colonies of *Myotis lucifugus*, and Smith and Goodpasture (5) who experimented with a nursery colony of *Eptesicus fuscus*. Most of these experiments have dealt mainly with the distance from which bats have homed. In almost all cases the percentage of returns has been small and only in a few cases has the homing been rapid.

The emphasis in our experiments was placed on distance, time, and percentage of return. Because we were working with nursery colonies in which there were many hiding places and numerous exits, we found it impossible to use conventional methods of tagging, therefore radioactive tagging was the method used in our study.

Method: Regular U. S. Fish and Wildlife Service metal bands were used. To the inside of each band was pipetted 5 lambdas (100 microcuries) of gold-198 Aurcoloid solution. The droplet was dried under an infrared lamp and was covered with a thin coat of clear fingernail polish. Each band was detectable through a two-inch thickness of wood, tin, brick, slate, etc., and enabled us to record high percentages of returns when the bats were completely hidden. Bats were collected in the nursery colonies by hand and with hand nets and were not banded until they had been taken to the point of release. The bats were detected upon return to the colonies with a NMC Model #GS-sL Survey Meter. Estimates of total returns were based on (1) the number of spots in which the radiation was detected, and (2) the intensity of radiation in these areas.

Myotis lucifugus

The colonies of *Myotis lucifugus* used in our experiments are located at Brookville, Indiana, one in the attic of St. Michael's school and the other in the steeple of St. Michael's church. These two colonies are just across the street from each other.

Our experiment with *Myotis* was carried out in the attic of St. Michael's school on the night of July 14. Forty female *M. lucifugus* were collected from 5:30 to 6:00 p.m. They were banded with radioactive bands between 9:00 and 9:34 p. m. and released 20 air miles due west of the nursing colony. The first bat was discovered back in the attic of the

1. The writers are indebted to William K. Stephenson for his valuable technical assistance in laboratory procedure. We also are indebted to David Telfair for his assistance with the monitoring equipment. Special thanks go to the National Science Foundation grant which made the study possible.

school at 1:55 a.m. A thorough monitoring of the attic takes a good deal of time, which means that the bat could have arrived any time between 12:30 and 1:55 a.m., because the first check ended at 12:30. Other concentrations of radiation were detected at: 2:20 (3 bats), 2:30 (6-7), 2:35 (4-5), 2:45 (9-10), 2:50 (7-8). Because of the number of places in which we found radiation and the amount of activity at these places, we estimated that 80-90% of the banded bats had returned by 3:00 a.m.

We wanted to find if there were any interchange between the school and the church. At 4:45 a.m. a check was made in the steeple for radiation. Radiation was detected, which indicated that approximately 4 bats or 10% of the total number banded were in the steeple. This illustrated the tendency of bats to return to the general vicinity of their home roost as described by Gifford and Griffin (2) and Twente (5). However, as the data indicates, the percentage of interchange was rather low, but it definitely proves that there is an interchange between these colonies.

We believe that it is significant that 80-90% of the bats returned in a matter of hours. If we had used the conventional method of banding, we would have recorded only a return of 2.5%, because only two of these bats were seen. The rest were hidden between boards of the roof and the tin roofing itself.

We believe that the flying time of these bats is also significant. The first bat we discovered had a maximum flying time of four hours and fifty-five minutes. It is possible that it did not come directly into the attic as soon as it reached Brookville; also it is possible that it could have been in the attic at least an hour before it was discovered. Flights of this type would give little time for random wandering. The bats would almost have to have a knowledge of the territory within a 20-mile radius or a direct homing instinct.

The theory that they have a direct homing instinct can be substantiated by the fact that as soon as they were released, they flew directly toward the nursery colony. This is in contrast to studies made by the senior author (unpublished) in which he liberated *Myotis* in the daytime and watched them with binoculars. He noted that they flew to the nearest cover, rather than to the home roost.

In future experiments in which it is desirable to determine how fast a flight these bats are capable of making over short distances better data could be obtained by collecting the bats late at night after they have returned from feeding, and releasing them shortly before daybreak. In this way we would have a better idea of their actual flight time, because it is probable that they would not feed on the way, and that they would enter the building immediately upon return.

Eptesicus fuscus

The majority of our experiments were done with nursery colonies of *Eptesicus fuscus* because there were more colonies of this species available in our area. One of the first experiments which we did with this species was in the attic of St. Michael's church at Brookville, Indiana. This was a nursery colony of about 75 adults. On the night of July 14 we banded and released 16 females and four males with radioactive bands 20 miles

due west of Brookville. We collected these bats between 6:00 and 6:30 p.m. and released them between 8:45 and 9:00 p.m. The first concentration of radiation back in the attic of the church was detected at 1:05 a.m., behind a brick wall. Because two separate spots of activity were detected through this wall, we feel safe in saying that at least two had returned. Other concentrations of radiation were detected at the following times: 1:30 (1-2), 3:00 (1), 3:44 (1), 4:10 (5-6), and 4:16 (4-6). By 4:30 a.m., we estimated that 70-90% had returned.

The next experiment was conducted with a nursing colony in St. Mary's of the Rock Catholic church near Batesville, Indiana. On the night of July 14, 37 adult females and 10 adult males were collected. These were banded and released on July 15 with radioactive bands, between 1:00 and 2:00 p.m. 40 miles due south of St. Mary's. These bats did not return the first night. However, on the night of July 16, the bats were detected during our first monitoring of the attic at 10:05 p.m. We were able to collect four of these which we kept until 6:00 a.m. At 5:00 a.m., two spots were found in one corner under a tin cornice which runs along the outside edge of the roof. The bats were between this and the 2" x 8" roof rafters to which the cornice was fastened. It was estimated that 4-6 were in one spot, and 7-9 in the other. Because of the amount of activity we feel that there were not more than 31-40% returns.

On July 14, 10 females and 1 male *Eptesicus fuscus* were collected at 8:00 a.m., on the John Longstreth place just north of Richmond, Indiana. These were taken 100 miles due north, banded with radioactive bands, and released between noon and 12:15 p.m. Three days later the bats were detected back at the home roost. They had arrived some time during the third night. In monitoring the barn we found six places of radiation. Some bats were hanging in the crest of the roof along with some unbanded ones. Others were between the new tin roof and the older shingle roof. We estimated from two to three bats in two of these places, another spot had from one to two, and the other spots had only one bat. Although only a small percentage could be seen, the others were readily detected. This was a total return of eight to eleven bats, or 72.7 to 100%.

Another homing experiment was started July 20. In this experiment bats were collected from two different colonies. Thirty-six adult females were collected at Milton, Indiana and 33 adult females at Longstreth's. The bats from Milton, collected between 6:00 and 7:00 a.m., were banded with radioactive bands and released between 10:25 and 10:50 p.m. 250 air miles due south of Milton. The bats from Richmond which were collected between 8:00 and 8:30 a.m., were banded and released between 8:35 and 9:05 p.m. 250 air miles due south of Richmond.

The first monitoring of the nursery colony at Milton was on the evening of July 24. We could not gain access to the building until 9:30 o'clock. The monitoring began at 9:45; at this time we discovered some radiation behind a brick wall. This was probably only one bat because the radiation could not be detected a few minutes later. It is probable that this bat had gone to feed. At least two bats were detected later in the night, at 12:45 a.m. At 7:30 a.m. we detected a total of five, a return of 13.8% by the end of the fifth night. We are confident that the bat which we detected at 9:45 had returned some time during the fourth night,

perhaps along with others which had already left to feed before we could monitor the building. The next day we made another check on the colony and at this time we were certain that almost all the bats were back because there were many hot spots and the background was considerably higher than normal. We estimated that at least 85% must have returned by this time.

A check on the colony at Richmond was not made until the morning of July 25, at which time we collected two of our banded bats. We were unable, however, to make an estimate of the returns because the building was still contaminated from the earlier experiment on July 14.

A duplicate of this experiment was performed with the Wilbur Holzback colony near Andersonville, Indiana. On August 4, 14 females and 5 males were banded with radioactive bands and released between 6:00 and 6:25 p.m. 250 miles due north of Andersonville. A check was made following the third night and checks were made continually during the fourth night, but no bats were discovered until 6:00 a.m. following the fourth night. At this time only one bat was discovered. Although several checks were made on subsequent days, no more bats were discovered on the home roost. See Table 1.

TABLE 1

Results of *Eptesicus fuscus* Homing Experiments

Date	Distance Transported	Number Released	Estimated Returns: No.	%	Elapsed time before return
July 14	20 mi. W	20 Ad. F	14–18	70–90	4 hrs. 20 min. – 8 hrs. 45 min.
July 15	40 mi. S	37 Ad. F 10 Ad. M	15–19	32–40	2 nights
July 14	100 mi. N	10 Ad. F 1 Ad. M	8–11	73–100	3 nights
July 20	250 mi. S	36 Ad. F	31	85	4 nights–6 nights
Aug. 4	250 mi. N	13 Ad. F 5 Ad. M	1	6	4 nights

These experiments with *Eptesicus* show that these bats are capable of long and rapid flights. However, as Gifford and Griffin (2) have suggested, this ability is used to a great extent early in the summer and to a lesser extent as the summer progresses. Evidently the group of bats which were taken 250 miles south possessed a much stronger homing instinct than did those which were taken 250 miles north 15 days later.

We believe that in future experiments of this nature more significant results would be achieved for a comparison if both groups of bats were taken from the same general vicinity and released in the opposite direction at the same time.

Summary

Homing experiments with summer nursery colonies of *Myotis lucifugus* and *Eptesicus fuscus* were conducted. Radioactive gold-198 was

used to tag the bats and a portable survey meter was used to locate individual bats in the nursery colonies. From 75-80% of a group of *Myotis lucifugus* released 20 miles west of their home colony returned between 4 hrs. 55 min. and 6 hrs. later. A total of 10% returned not to the home colony but to a nearby colony at the end of 7 hrs. 45 min. A total of 36 *Eptesicus fuscus* were taken 250 miles south and released, and 85% of these returned by the sixth night. Only one *Eptesicus fuscus* of 18 released 250 miles north returned. This was found on the fourth night. Subsequent checks showed no additional returns. Other experiments with *Eptesicus* yielded returns ranging from 31-40% in two nights from a distance of 40 miles to 72-100% in three nights from a distance of 100 miles. All experiments emphasized the value of radioactive tagging, for in none of the experiments did the number of banded bats collected or seen at the home roost exceed 10%.

Literature Cited

1. COCKRUM, E. L. 1956. Homing, Movements, and Longevity of Bats. Jour. Mamm. **37** : 48-57.
2. GIFFORD, CAMERON E., and GRIFFIN, D. R. 1960. Notes on Homing and Migratory Behavior of Bats. Ecology **41** : 378-381.
3. HOWELL, A. B., and LITTLE, L. 1924. Additional Notes on California Bats. Jour. Mamm. **5** : 261-263.
4. MUELLER, H. C., and EMLEN, J. T. JR. 1957. Homing in Bats. Science **126** (3268) : 307-308.
5. SMITH, E., and GOODPASTER, W. 1960. Homing in Non-migratory Bats. Science : Mar. 21, 1960.
6. TWENTE, J. W. 1955. Aspects of a Population Study of Cavern-dwelling Bats. Jour. Mamm. **36** : 379-390.

Distribution of the 13-lined Ground Squirrel in Indiana

Russell E. Mumford, Purdue University, and Ralph D. Kirkpatrick, Oklahoma State University

The 13-lined ground squirrel *(Citellus tridecemlineatus)* was formerly restricted to the prairie portions of Indiana. Evermann and Butler (1) recorded it from seven counties, and Hahn (2) added reports from seven additional counties. Between 1909 and 1936, there was evidently an extension of range into east-central Indiana, but it is impossible to determine whether or not part of this apparent shift in distribution was because of insufficient knowledge resulting from limited field work. Lyon (3) listed observations from 34 counties, but knew of preserved specimens from only 6 of these.

We began collecting specimens of *Citellus* in 1958, after learning that the species was then found outside the known range of 1936, and tried to collect at least one specimen in each county where the animal occurs. As a result, it is now possible to map the current range with considerable accuracy. There are specimens of *Citellus tridecemlineatus* in museums from 42 counties and sight records from 8 more (Figure 1). In our attempt to chronicle what seems to us to be a recent and continuing range extension of this squirrel, we obtained pertinent information from interviews, field work, and examination of preserved specimens in various collections, as follows:

1. Franklin County. Dale Hood, conservation officer, observed this ground squirrel near Fairfield in 1956. As early as 1862, the species was present in Butler County, Ohio, 20 miles east of Franklin County, Indiana. It may be possible that some of the animals reached Indiana from this Ohio site.

2. Johnson County. One of us (RDK) took a specimen at Mt. Pleasant Cemetery, 7 miles east of Franklin, May 7, 1959. On this date, the caretaker, who had worked at this cemetery since 1947, said he first saw ground squirrels there in 1954.

3. Shelby County. Aaron Nigh of the Indiana Department of Conservation, who has lived in the county 40 years, saw the first *Citellus* in 1948, when a farmer brought one in for identification. It had been killed 2 miles north of Morristown. Our specimen was taken in 1959 at Fountaintown.

4. Union County. Dale Hood saw a ground squirrel approximately 3 miles south of Liberty, between 1957 and 1959.

5. Wayne County. A specimen in the Joseph Moore Museum, Earlham College, was taken at Centerville in 1948.

The 13-lined ground squirrel is most frequently found in cemeteries and pastures, on golf courses, or along road shoulders and railroad embankments. It shuns the woods. Land usage patterns following logging and drainage no doubt enabled the species to take up new range in the farmlands of central and eastern Indiana. It may have dispersed into these new areas along railroads and other roadways. We hope to obtain speci-

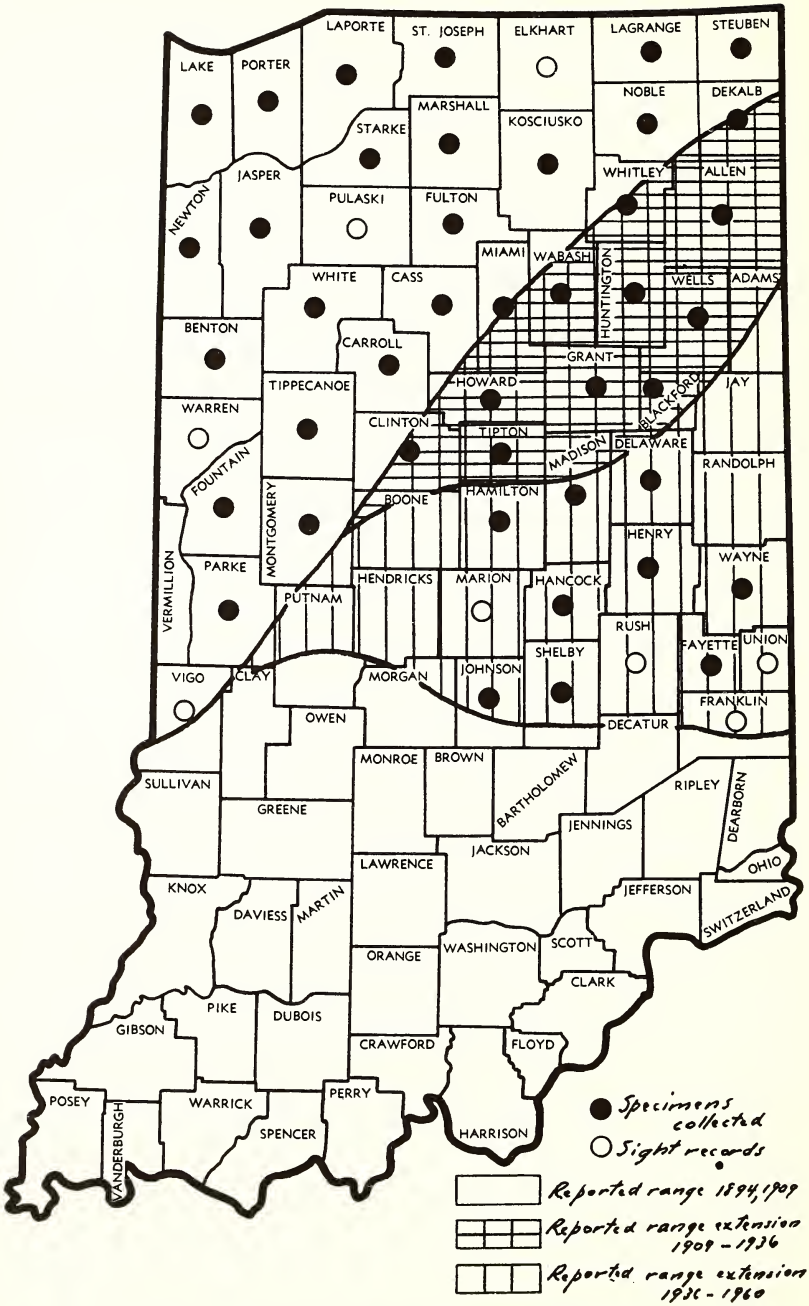


Figure 1. Distribution of *Citellus tridecemlineatus* in Indiana.

mens from other counties where *Citellus* has been reported and to obtain data on any future distribution changes.

Literature Cited

1. EVERMANN, B. W., and A. W. BUTLER. 1894. Preliminary List of Indiana Mammals. Proc. Ind. Acad. Sci. for 1893 : 128-9.
2. HAHN, W. L. 1909. The Mammals of Indiana. 33rd Ann. Rept. Dept. Geol. Nat. Resources Indiana : 475-478.
3. LYON, M. W., JR. 1936. Mammals of Indiana. Amer. Midl. Nat. 17 : 179-182.

A Postfemoral Spot in *Plethodon*

ALBERT E. REYNOLDS, DePauw University

This paper is to report the occurrence of, and to present a preliminary description of, a morphological feature exhibited by certain salamanders of the genus *Plethodon*. Initiation of an investigation on inter-relationships among certain *Plethodons* was begun in the summer of 1956 by intensive study of live but chloretone-anesthetized specimens of *Plethodon jordani melaventris*. The author was up to that time acquainted with *P. j. melaventris* only by reading in the literature, and was both unprepared and surprised to observe that these animals exhibited a small oval area of lighter color located postero-dorsal to the junction of the thigh and trunk. Characterized by Pope and Hairston (10) as "immaculate . . . with a black belly," this salamander is so completely black that any pigment-free area, or any significant reduction in pigmentation intensity, is strikingly evident. This lighter oval area was first noted macroscopically in animals swimming about in finger bowls of dilute chloretone during the anesthetization period. Its consistency of appearance led to its being recorded on data sheets, and for conciseness it was termed a "postfemoral spot."

This report is based on factual data which have been derived from specimens collected in central Indiana and also in the Southern Appalachians where the Highlands Biological Station, Highlands, North Carolina, was the base of operations, and includes specimens accumulated over five warm-weather seasons (1956-1960, inclusive). During the summers of 1956 and 1957 the work was aided by National Science Foundation grants administered by the Highlands Biological Station. Administered by DePauw University, continued work in the Southern Appalachians was aided by grants from the Eli Lilly Company and the Esso Educational Foundation in the summers, respectively, of 1958 and 1959. A grant from the Research Fund of the Indiana Academy of Science provided certain materials used in the histological preparations. For guidance and helpful advice, grateful acknowledgement is made to Professor Thelma Howell, Executive Director of the Highlands Biological Station, to Mr. Arthur Stupka, Naturalist, Great Smoky Mountain National Park, and to Mrs. C. P. Hickman at DePauw for photomicrographic assistance.

Description and Occurrence of the Postfemoral Spot

Plethodon jordani melaventris

The postfemoral spot illustrated in Figure 1 indicates the general size and shape of the spot in relation to its anatomical context. The longer dimensions were around 1.5 to 1.8 mm, the lesser dimensions or greatest widths were about 0.5 to 0.6 mm, and the spot was uniformly ovoid. The spots of different specimens were not uniform, but varied in vividness or degree of lightness as compared to the black of surrounding skin.

Under magnification by the binocular dissecting microscope (10X and 30X), any "normal" or "typical" skin of the posterior dorsal or dorsolateral area presented the visual impression of solid black interrupted by small white areas which represented the conical, tapering,

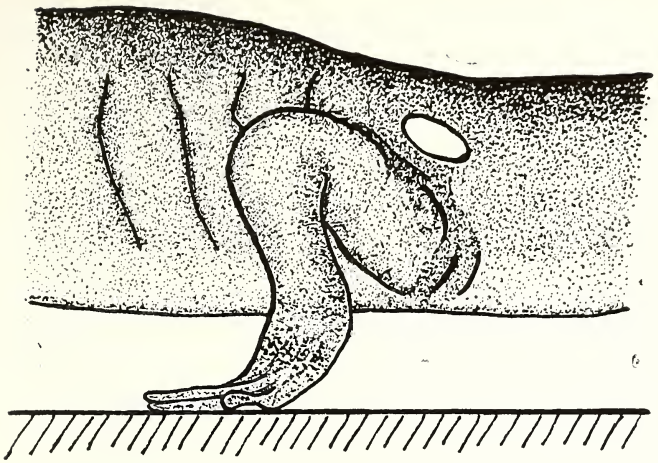


Figure 1. Semi-diagrammatic representation of the left side of *P. j. melaventris* No. 167 at pelvic level. Deliberately over-emphasized, the postfemeoral spot is shown as an oval white area postero-dorsal to the junction of thigh and trunk (x 3, approximately).

superficial ends of flesh-colored skin glands. The black, closely-compacted melanophores appeared to be right at the surface, but if the skin were touched with a probe or teasing needle and either depressed or wrinkled, it became apparent that the black-containing layer was overlaid by a thin epidermis of almost perfect transparency. Within the oval area of the postfemoral spot, however, the melanophores were very deep within the skin, and were overlaid by a correspondingly thickened layer of clear tissue. Examination along the edges of the spot clearly revealed the melanophores sloping downward as they receded from a superficial to a deeper and more basal position within the dermis; these edges also revealed clearly the compensatory thickening of the overlying clear tissue as the melanophores sloped downward to the deeper position. While translucent to the point of almost complete transparency, under certain angles of observation and certain conditions of lighting, this clear overlying tissue seemed to have a slightly bluish or grayish hue which gave it a glazed or sheen-like appearance.

In addition to the deep and basal position, the melanophores within the spot area were much less closely-compacted, less densely concentrated, than was the case in adjacent typical skin. This reduction in melanophore concentration was, as to degree, readily correlated with the variations in vividness or degree of lightness of postfemoral spots mentioned above. In some of the postfemoral spots which were most vivid and easily detected by the naked eye, only a few scattered and isolated melanophores could be seen deep in the dermis with the aid of the binocular microscope.

To get some clue as to the underlying basis of the postfemoral spot in terms of skin organization, extension of the study into the realm of the histological was undertaken. The tissue excised included the postfemoral spot plus a small expanse of surrounding typical skin. Spread

on a small piece of cardboard to prevent curling, this was plunged into Bouins fluid for for fixation. Imbedded in paraffin and sectioned at 8 microns, the tissues were stained in a combination of Delafield's hematoxylin and Mallory's triple stain, and finally mounted in balsam. Due to the preliminary nature of this phase of the investigation, it is not yet possible to give statistical results, so descriptive comment will be made on an average case.

From one such average case, Figure 2 shows a cross-section which included the postfemoral spot and adjacent non-spot skin. The latter, in

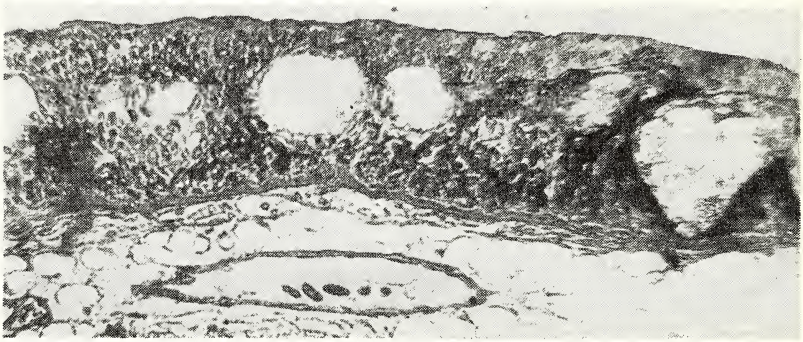


Figure 2. Section of postfemoral skin from *P. j. melaventris* No. 138 showing about half the postfemoral spot and some typical non-spot skin at the right. On the right, note heart-shaped granular gland in non-spot skin with thickly-clustered melanophores occupying most of dermal thickness. Note downward slope of melanophores to the thin and fragmentary occurrence in the spot; a small cluster of melanophores occurs to lower left of largest mucous gland near center of figure. Note thickenings of epidermis between mucous glands. Most basal layer of dermis is compact dermis consisting of wavy parallel connective tissue fibers.

this specimen, measured about 10 to 11.2 microns in thickness of which 1.4 to 2.2 microns was attributable to epidermis, 8.6 to 9.0 microns to dermis. Judged by the nuclear count, the epidermis was three to five cells thick, organized as a stratified epithelium. Just beneath it occurred, in non-spot skin, the spongy layer of the dermis; this included scattered connective tissue fibers randomly oriented, numerous nuclei, acini of mucous and granular glands, and melanophores. Occupying most of the dermal thickness, these melanophores were very numerous and overlapped each other; in general melanophores occurred from the lower epidermal border down into the dermis to a level about 1.2 microns above the basal border of the dermis. This deep 1.2 microns of melanophore-free dermis consisted of a small portion of the spongy dermis and all of the compact dermis which was made up largely of connective tissue fibers oriented parallel to each other and to the skin surface.

In the postfemoral spot, reference to the middle of Figure 2 indicates that the melanophores were reduced to a fragmentary layer of deeply-situated and scattered melanophores above which occurred the clear overlying tissues that were described above from surface observation as being thickened in a compensatory manner. These can be seen to consist of

dermal elements devoid of melanophores plus an epidermis somewhat thickened except just above skin glands; the stretches of thickened epidermis usually measured 3.6 to 4.0 microns, and one measurement of 7.6 microns has been noted. No granular glands have as yet been observed in the postfemoral spot, though mucous glands occurred there to a normal extent. The downward slope of melanophores at the postfemoral spot edge is evident in Figure 2 which also indicates that what was described above as a recession to deeper location was not only that but also a drastic reduction of dermal thickness occupied by melanophores.

The *Plethodon jordani* Complex

The above data on *P. j. melaventris* represent observations on representatives from one of seven populations currently recognized as subspecies of *Plethodon jordani* (Schmidt, 11). The postfemoral spot has been seen in 92 specimens of *melaventris* collected from a varied sampling of its range. In addition, 14 live specimens on hand as of this writing clearly evince the postfemoral spot to macroscopic observation. In this total of 106 animals, all observed alive, young stages as well as adults of both sexes are represented.

Collecting in the Southern Appalachians was accomplished along certain transects which extended through the range of *P. j. melaventris* and on into the ranges of some of the adjacent populations. The number of specimens studied from each of these adjacent populations was, of course, considerably less than the number of *melaventris* reported on above. Data sheets on eight specimens of the red-legged *P. j. shermani* contained descriptions of the postfemoral spot, and in addition two live specimens currently on hand exhibit the spot to the naked eye. Records on 17 specimens of *P. j. rabunensis* describe the spot as also do records on four specimens of the nominate population, the red-cheeked *P. j. jordani* of the Great Smoky Mountains. In the small numbers of these near-relatives of *melaventris* that have been studied, the postfemoral spot agreed so closely with the spot of that form that no further description is necessary.

Plethodon glutinosus

This species, the slimy salamander, is widely distributed over a range that encompasses most of the eastern half of the United States (Dunn, 3; Bishop, 2) hence it not only occurs in Indiana but also overlaps geographically and in some cases altitudinally (Hairston, 6, 8) the mountain-dwelling and restricted-range members of the *P. jordani* complex of the Southern Appalachians. In the latter area, use of the transect method involved collection at lower altitudes and the taking of specimens of *glutinosus*.

Careful comparison of one dozen cases from central Indiana with an equal number of *glutinosus* from the Southern Appalachians revealed no essential differences with respect to manifestation of the postfemoral spot, at least as seen in surface view; no histologic preparations on *glutinosus* skin have as yet been completed. In this species the postfemoral spot is not visible to the naked eye, the reason becoming apparent when the specimens were observed under magnification. There was no reduction of melanophoric concentration within the spot area; melanophores appeared to be as closely-compacted in the spot as elsewhere in surrounding

skin. However, the spot area could be identified as an oval area wherein the melanophores receded to a more basal and deeper position, and wherein there was compensatory thickening of the clear overlying tissue. From both collection areas typical spot measurements were 1.6 x 0.9 mm, 2.1 x 0.9 mm, and 1.4 x 0.6 mm in adult specimens. In some cases the recession to deeper location involved not only melanophores but also the glistening, crystalline-appearing, dead-white spots made up of iridophores which are so characteristic of *P. glutinosus*.

Small *Plethodons*

In addition to the large salamander just discussed, *Plethodon cinereus* and *Plethodon dorsalis* are species of small salamanders which also occur in Indiana. As compared to the predominant black of the former, these two small species have brown melanophores and also exhibit more variegated colors since they have white, red, and yellow chromatophores as well as some pigment-free spots of flesh color.

In neither of these small *Plethodons* could a postfemoral spot be readily recognized, yet under magnifications of 10x and 30x certain aspects of the spot pattern were clearly evident. Live *dorsalis* exhibited an oval area corresponding to the spot location wherein the melanophores sloped off to a deeper position in a very characteristic manner, and wherein the clear superficial tissues correspondingly thickened. In most of these salamanders there occurred in the spot area a number of single, isolated, white iridophoric flecks which lay deep in the overlying clear tissue yet superficial to the deepened melanophores. In *dorsalis* there was furthermore a very slight, yet detectable, reduction in concentration of these deep postfemoral spot melanophores; in *cinereus*, on the other hand, there was no such reduction of concentration. Otherwise the *cinereus* spot was much like that of *dorsalis* save in these respects: (a) instead of isolated white flecks, whole spots made up of massed white chromatophores were involved in the chromatophoric retreat to deeper position, and (b) in the *cinereus* spot area there occurred a number of large capillaries which gave the area a slightly pink hue.

Discussion

In its most diagrammatic form, as seen in the skin of *P. j. melaventris*, the unique and distinctive characteristics of the postfemoral spot would include: (1) restriction of the chromatophores to a deeply recessed position basally in the dermis; (2) overlying the recessed chromatophores, a correspondingly thickened layer of clear and nearly transparent tissue; (3) reduction of compactness or concentration in the deeply-located chromatophores. The significance of this morphologic pattern is unclear; whether the postfemoral spot is in any way correlated with skeletal or muscular conditions in its anatomic area, or whether indeed it has any adaptive significance at all, must await more data and further study. However, the data presented above have made a reasonably strong case for the occurrence of this diagrammatic pattern or some modification of it in no less than three species of *Plethodon* plus four subspecies of a fourth species. This prevalence of occurrence might be interpreted as prima facie evidence for genetic control of the spot, and this in turn raises the interesting speculation that the variations shown to exist in

manifestation of the spot might represent restrictions on free gene flow between populations.

It may be noteworthy here to recall that the red-legged salamander of the Nantahala Mountains was originally described in 1906 as *Plethodon shermani* (Dunn, 3), and that it retained specific status for three and one-half decades until Bishop (1) relegated it to a subspecies as *Plethodon glutinosus shermani* (see also Bishop, 2). Rejected by Grobman (4), this relationship between *shermani* and *glutinosus* was also denied by Hairston and Pope (5) and Hairston (7), but the current view by which *shermani* constitutes one of seven subspecies of *P. jordani* has been challenged (Mittleman, 9). There furthermore exists admitted uncertainty concerning the true relationships between *glutinosus* and the members of the *jordani* complex, particularly with respect to *shermani* (Hairston, 7). It is this type of uncertainty which renders most intriguing any morphological situation which gives promise of shedding light on the problem of gene flow and possible variations therein, which additional study of the postfemoral spot might very well do.

Summary

The postfemoral spot is an oval patch of skin located postero-dorsal to the junction of the thigh and trunk which is characterized by (1) reduction of melanophoric concentration, (2) recession of such melanophores as do exist in the spot to a deep dermal position, (3) overlying the deepened melanophores, correspondingly thickened clear and pigment-free tissues made up of dermal elements and thickened epidermis. This spot is exhibited in its most diagrammatic form by *Plethodon jordani melaventris* in which the spot has been seen in over 100 specimens and in which preliminary histologic studies have verified the characteristics observed from surface view. Limited studies on fewer specimens, and from surface examination only, indicate that a similar spot is characteristic of *P. j. shermani*, *P. j. rabunensis*, and *P. j. jordani*. *Plethodon glutinosus* from both the Southern Appalachians and central Indiana, as well as *P. cinereus* and *P. dorsalis* from the latter region, all exhibit modified forms of the diagrammatic postfemoral spot. The possible significance of this spot for speciative studies is discussed briefly.

Literature Cited

1. BISHOP, SHERMAN C. 1941. Notes on Salamanders with Descriptions of Several New Forms. Occ. Pap, Mus. Zool. Univ. Mich., No. 451, pp. 1-25.
2. BISHOP, SHERMAN C. 1947. Handbook of Salamanders. Comstock Publishing Company, Ithaca, New York.
3. DUNN, EMMETT REID. 1926. The Salamanders of the Family Plethodontidae. Smith College 50th Anniversary Publication, Northampton, Mass.
4. GROBMAN, ARNOLD B. 1944. The Distribution of the Salamanders of the Genus *Plethodon* in Eastern United States and Canada. Ann. N. Y. Acad. Sci. Vol. XLV, Art. 7, pp. 261-316.
5. HAIRSTON, NELSON G., and CLIFFORD H. POPE. 1948. Geographic Variation and Speciation in Appalachian Salamanders. Evolution 2 : 266-278.
6. HAIRSTON, NELSON G. 1949. The Local Distribution and Ecology of the Plethodontid Salamanders of the Southern Appalachians. Ecol. Monogr. 19 : 47-73.
7. HAIRSTON, NELSON G. 1950. Intergradation in Appalachian Salamanders of the Genus *Plethodon*. Copeia, 1950, No. 4, pp. 262-273.

8. HAIRSTON, NELSON G. 1951. Interspecies Competition and Its Probable Influence Upon the Vertical Distribution of Appalachian Salamanders of the Genus *Plethodon*. Ecology **32** : 266-274.

9. MITTLEMAN, M. B. 1948. American Caudata. V. Notes on Certain Appalachian Salamanders of the Genus *Plethodon*. Jour. Wash. Acad. Sci. **38** : 416-419.

10. POPE, CLIFFORD H., and NELSON G. HAIRSTON. 1948. Two New Subspecies of the Salamander, *Plethodon shermani*. Copeia, 1948, No. 2, pp. 106-107.

11. SCHMIDT, KARL P. 1953. A Check List of North American Amphibians and Reptiles. Amer. Soc. Ich. and Herp.

Some Effects of High and Low Incubating Temperatures on Chick Behavior[1]

W. C. Gunther, R. K. Jones, and Paul Manske, Valparaiso University

Introduction

This report is concerned with the investigation of the post-hatching behavior of Leghorn chicks which were incubated at abnormal temperatures during the first stages of their embryonic life.

Several investigators have concerned themselves with the effects of abnormal incubation temperatures upon the development of the chick embryo (1-7). Gunther (3) appears to have been the first investigator to make a systematic study of the behavior of chicks hatched from eggs subjected to abnormal temperatures.

The project reported herein is the initial stage of a much larger research understaking on the part of the senior author. In carrying out this larger undertaking, the investigators will consider a greater range of abnormal incubation temperatures and will investigate the development of the neural tube of embryos when it has been established that there is abnormal behavior in hatched birds which were incubated under similar conditions. Consequently, the prime objective of this initial project was to detect and make note of any significant behavioral differences between the groups being investigated. The projected implication of positive results in this and successive projects is the possibility that the aberrant behavior of mentally retarded human beings might conceivably be the result of similar temperature abnormalities during the gestation period.

Methods

In Part I of this project the authors compared the behavior of chicks hatched from eggs incubated at temperatures above the normal incubation temperature with the behavior of a control group hatched from eggs incubated at normal temperatures. Part II of the project was concerned with the behavior of chicks hatched from eggs incubated at temperatures below normal.

In both groups simple observational tests were devised to study differences in behavior. These are described below. Movies were made of the animals as they were put through the various tests. In addition, some of the animals mentioned in Part II were tested in a T-maze and in a discrimination apparatus, the details of which are presented in the appropriate section.

Materials, Results, and Discussion

Part I

Twenty-four Leghorn chicken eggs were incubated at the normal temperature, 37.5° (all temperatures herein are reported as centigrade), in a Montgomery Ward Standard Forced Air 416-egg incubator. Twenty-

1. This investigation was supported in part by research grant B-2128 from the Neurological Diseases and Blindness Council, National Institutes of Health, Public Health Service, United States Department of Health, Education and Welfare.

one chicks hatched within 22 days. One of the chicks hatched with a poorly developed leg which caused it to walk with a limp.

Twelve chicken eggs were incubated at 41° for 5 days in a round portable incubator and were then placed in the Montgomery Ward incubator at 37.5° for the remainder of the incubation period. Five chicks hatched within 23 days. One of these chicks had a poorly developed leg and walked with a limp. (Hereafter, the chicks in this group will be referred to as the "abnormals." This designation is used in reference to the abnormal incubation temperature.)

The chicks in both groups were observed frequently for 5 weeks in a 3′ x 3′ demonstration box for periods of 15 to 30 minutes. Motion pictures were taken when the chicks were 2, 22, and 32 days old, and many behavioral differences between the groups are evident in these films.

The most notable differences were the greater social aggressiveness and activeness of the normals and the apparently heightened "fear" response shown by the abnormals. This statement is based on the following observations:

1. The normals pecked at the floor, at scraps of newspaper, at knotholes in the wooden demonstration box, etc. While the abnormals carried on similar activities, they did so much less frequently.

2. The normal birds sauntered around the demonstration area quite freely without demonstrating any hesitancy. The abnormals, on the other hand, tended to move with short, jerky movements—almost reluctant to proceed without first looking around. The abnormals were quite hesitant about investigating strange objects, such as an aluminum water pan, while the normals were curious about such objects and did not seem to be afraid of them.

3. Frequently the chicks were intentionally startled by clapping hands, scraping a metal chair across the concrete floor, exploding firecrackers, and by shouting. The animals in the two groups responded quite differently to these types of stimulation. The normals tended to scatter around the demonstration box in response to the stimuli. When the abnormals were exposed to the same stimuli they huddled together or congregated in a corner. Even when one of the investigators attempted to scatter them by waving a hand at them, the chicks continued to cower in the corner. This difference was observed consistently.

4. The normals were highly competitive. They often contested for the same piece of food or the same scrap of paper. The abnormals seemed quite satisfied with the food in front of them and did not concern themselves with the activities of the other animals in their group.

5. The normals not only pecked frequently at inanimate objects, but also pecked at, and fought with, each other. The abnormals never fought among themselves.

These observations suggested to the investigators that the normal chicks tended to be more aggressive, more active, and less fearful than the abnormal birds.

There were also certain physical differences between the two groups. The feather coat of the abnormals was noticeably poorer than that of the normals and took longer to develop, patches of exposed skin being clearly

evident even after 7 days. The crippled abnormal chick died when it was 8 days old. An autopsy revealed a very poorly developed digestive tract. There were no apparent differences in the motor responses of the two groups.

Part II

Twelve chicken eggs were incubated at normal temperatures in the same manner as that described in Part I. Eight chicks hatched within 22 days.

Twenty-four eggs were incubated at 34° for 10 days and then placed into the 37.5° incubator. Three chicks hatched within 22 days, one of which had a crippled leg. The term "abnormals" will now be used to refer to this group of chicks.

These animals were observed in the same manner as those in Part I. There were no apparent physical differences and, once again, the motor responses of the two groups were not noticeably different. However, the abnormals seemed to be more hostile and more sensitive and responsive to environmental stimulation than were the normals. The abnormals also appeared restless, hypertense, and hyperexcitable. These inferences are based on the following observations:

1. The abnormals seemed to tear newspaper and peck at the floor more viciously than did the normals.

2. Six chicks were handled every day for psychological testing (to be described in detail below). Not once did the normals peck at the hands of the investigator who was working with them; nor, for that matter, did any of the normals described in Part I above. The abnormals, on the other hand, frequently pecked the investigator's hands when they were handled. Such behavior might be understandable if the chicks had been handled infrequently. Even normal chicks could be expected to peck under such circumstances. Since they were handled every day, the pecking would appear to suggest restlessness, hypersensitivity, and excitability on the part of the abnormal animals.

3. It appears to be normal behavior for chicks to peck at crippled birds in the community. This behavior was observed in both groups of chicks in Part I, as well as in the abnormals in Part II. Neither of the crippled chicks in Part I attempted to fight back or retaliate, but each resigned itself to its low position in the pecking order. However, when the cripple from the Part II group of abnormals was pecked by other birds, it was quick to fight back in retaliation. It seemed to refuse to assume its low position in the pecking order simply because of its physical deformity.

4. Instead of retreating from a hand fluttered in front of them—as was the case with all other groups tested—these abnormals occasionally "stood up" to the investigator's hand and did not cower.

In addition to these differences which are thought to be evidences of hypersensitivity, hyperexcitability, greater restlessness and hostility among the abnormals, another deviation from normal behavior was noted. Pecking at knotholes appears to be an innate response of chickens. Although the abnormals pecked at the floor and at each other with regularity, they rarely pecked at the knotholes in the walls of the wooden demonstration box; certainly they did not do so as often as the normals did.

In an attempt to identify possible differences between the groups in terms of learning ability, the animals were run in a simple T-maze in which they learned a position response. Figure 1 is a diagram of the maze employed. The walls are 10⅞" high, the leg is 23" long, the arms

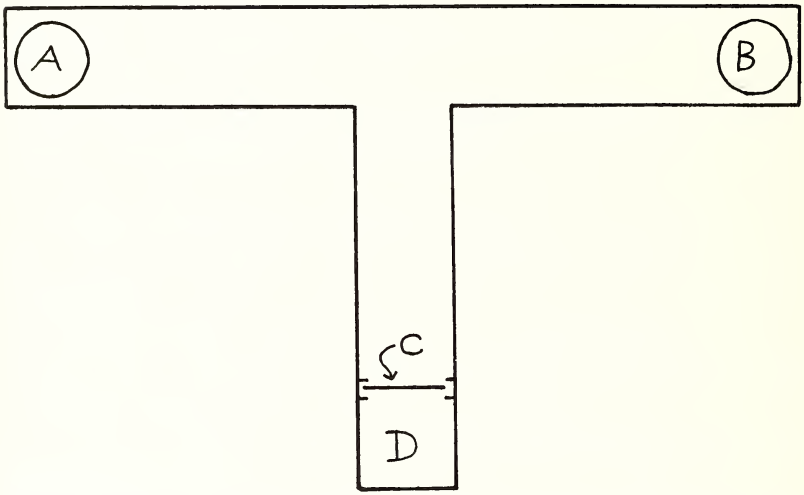


Figure 1. T-maze. A, false food well; B, food well; C, sliding panel door; D, starting box. See text for detailed description.

are each 24" long, and the alleys are 6" wide throughout. The interior of the maze is black, and during the tests it was illuminated by a 40-watt fluorescent bulb situated approximately one inch above the top of the maze and extending the length of the arms. The leg and arms of the maze are covered with a removable wire screen.

The animals proceeded from a 6" x 6" starting box and learned to execute a right turn at the choice-point in order to obtain food placed in the right arm of the maze. The left arm contained a false food receptacle; that is, the food, placed in one Petri dish covered by another Petri dish, could be seen but not obtained by the animals.

Four normal animals and two abnormal animals were each given one trial per day in the maze, from the 4th through the 33rd day after hatching. On the 21st through the 33rd days after hatching the animals were first run in a discrimination apparatus (to be described below) and subsequently in the T-maze. The animals were deprived of food but not water for approximately 12 hours prior to each testing period. The response measure obtained was running time in seconds on each trial.

Mean running times per trial were calculated for both groups, the times based upon the data for days 4 through 33 (all trials) and the data for days 21 through 33 (trials completed after the animals were introduced to the discrimination apparatus). The running times used in the computation of the means were for those days on which complete data were available for all animals. In Table 1 are given the group means per trial for days 4 through 33 and days 21 through 33.

Table 1. Mean running times per trial of 4 normal and 2 abnormal chicks (times are expressed in seconds)—differences between means are not significant.

Group	Days 4 through 33 (All trials)	Days 21 through 33 (Trials completed after animals were introduced to discrimination apparatus)
Normal	17.95	20.08
Abnormal	18.63	38.77

Although the means for the abnormal group are greater than those for the normal group, the differences failed to attain significance at the 5% level of confidence when tested by means of Student's "t-test." The larger difference between the group means for days 21 through 33 suggests that the T-maze performance of the abnormal animals may have been depressed by some aspect of the experience of performing in the discrimination apparatus. This point is discussed in detail later on.

In an effort to identify stimulus preferences which might subsequently be incorporated into tests of learning, a discrimination enclosure (Figure 2) 42″ long, 18″ wide, and 18″ high was designed. A 6″ x 6″ starting

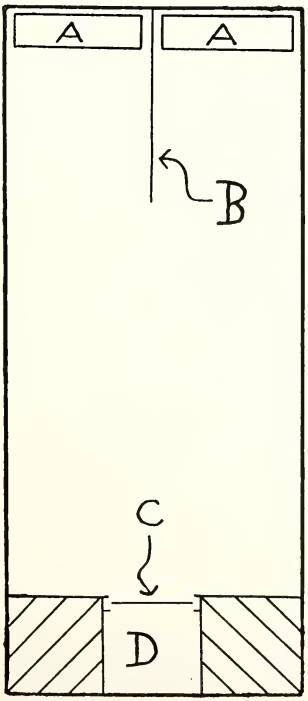


Figure 2. Discrimination apparatus. A, food trays; B, partition; C, sliding panel door; D, starting box. See text for detailed description.

box, with sliding panel door, is located at one end and a 12″ partition extends into the enclosure at the other end, separating this end into two presentation areas. The interior of the enclosure is painted a neutral gray. The stimuli employed were three removable food trays, each a different color. The food receptacles are 8¾″ x 2¼″ x 1½″ and have backs 12″ high. The three food trays are painted with Devoe Mirrolac Enamel, and the colors used are Chinese Red, Holland Blue, and Jade Green.

In the series of tests to be described the food trays were presented in pairs, both trays containing food on each presentation. The positions of the differently colored receptacles were randomized left and right in each series of trials. The 4 normal and 2 abnormal animals were each given 10 trials per day in the discrimination apparatus, from the 21st through the 33rd day after hatching. The animals were deprived of food but not water for approximately 12 hours prior to each test period. The following 3 color combinations were used in order of mention: red-green; red-blue; green-blue. The trials for each color combination were run on successive days, all animals receiving 30 trials on the red-green combination, 30 trials on the red-blue, and 40 on green-blue. Table 2 is a summary of the results of this series of tests.

Table 2. Stimulus preferences shown by 4 normal and 2 abnormal animals. Values of chi-square are based upon one degree of freedom. The double asterisk denotes significance beyond the 1% level of confidence.

Group	Stimulus combination	Preferred stimulus	Value of chi-square
Normal	red-green	red	20.28**
	red-blue	red	12.22**
	blue-green	none	1.70
Abnormal	red-green	red	9.12**
	red-blue	red	24.70**
	blue-green	none	0.15

Both the normal and the abnormal animals demonstrated significant preferences for the red stimulus over the green and for the red stimulus over the blue. Neither group showed a significant preference when presented with the blue-green combination.

No attempt was made to determine the extent to which the preferences manifested by the animals were functions of hue differences or of differences in reflection between the stimulus pairs.

Several qualitative observations of behavior of individual chicks may prove to be significant:

1. One of the abnormals consistently turned to the left in both the T-maze and the discrimination apparatus. When in the T-maze, it always investigated the false food well on the left before proceeding to the right food well. When on one occasion it did go initially to the correct food well, it first turned to the left and then had to twist itself to the right. It

seemed to know where the food was located but could not make the proper turn. When placed in the discrimination apparatus, the chick went to the food well to the left, regardless of the color choice involved. The animal was examined and no apparent physical abnormalities were found which might explain this favoring of a turn to the left over a turn to the right. It seems possible that the abnormal incubating temperature somehow affected the area of the brain which controls the learning of a response to the right.

2. The second abnormal chick was a so-called "master of the T-maze." It made very few incorrect turns and would proceed immediately and directly to the proper food well when placed in the T-maze. When introduced into the discrimination apparatus, it showed an immediate preference for the red stimulus over both the green and the blue. It was the only chick which maintained an exclusive preference for the red stimulus throughout all presentations of the red-green and red-blue combinations. Each day when placed in the T-maze—after going to the red food well in the discrimination apparatus for 10 consecutive trials—this chick seemed to lose its ability to comprehend the T-maze situation quickly as it had once been able to do. Instead of proceeding directly to the right food well as it had done prior to the beginning of the preference tests, it wandered about the maze and took 20 times longer to find the food than it did before it was run in the discrimination apparatus. Its initial concern appeared no longer to be the desire to satisfy hunger, but rather the desire to escape. This happened 7 consecutive days. When the red food tray was removed from the discrimination apparatus on the 8th, 9th, and 10th days and the blue and green trays were presented, the chick returned to its previously learned adaptive behavior in the T-maze and found the food quickly. In order to test the obvious hypothesis that the red food box was confusing the animal, the investigator again exposed the chick to the red food tray prior to putting it into the T-maze. Again the chick appeared to become completely confused and did not find the food until it had wandered aimlessly through the maze for some time.

This chick seemed to be able to learn one thing and one thing only. When the learning situation became complex, it appeared to forget everything but the most recently learned responses.

Behavior patterns similar to those just described were not observed among the normal animals. Since environmental influences were presumably homogeneous for both groups of chicks, it seems likely that the deviant behavior may have represented manifestations of the effect of the abnormal incubation temperature on the nervous system of the animals.

Summary

The behavior of chicks incubated at abnormal temperatures during the early stages of their embryonic life was compared with the behavior of chicks incubated at normal temperatures. The chicks which had been incubated for 5 days at 41° were less aggressive, more fearful, and, generally speaking, less active than the normally-incubated animals.

The chicks which had been incubated for 10 days at 34° were restless, hypertense, and hyperexcitable compared with the normal group of chicks. Although mean running times in the T-maze for the chicks incubated at

this subnormal temperature were higher than those for normal chicks, the mean differences failed to attain significance at the 5% level of confidence. On the other hand, for this same group, both normal and abnormal chicks showed highly significant preferences in a discrimination apparatus for the colors red over green and red over blue. None of the chicks tested showed a significant preference when presented with blue-green color combinations. The individual chicks of this abnormally incubated group demonstrated certain interesting behavioral patterns, which could possibly be interpreted as evidence of limited mental ability resulting in reduced ability to function adaptively.

The investigators realize that it is difficult to arrive at any definite conclusions on the basis of the above results. More temperatures must be considered, different behavioral situations must be presented, and refined techniques must be devised for testing. However, we do feel that the evidence from this particular project is indicative of a possible relationship between the temperatures at which chick embryos are incubated and the behavior of the hatched chickens.

Literature Cited

1. ALSOP, F. M. 1919. The effect of abnormal temperatures upon the developing nervous system in the chick embryo. Anat. Rec. **15** : 307-331.
2. FERE, CH. 1894. Note sur l'influence de la température sur l'incubation de l'oeuf de poule. Journ. de l'anatomie et de la physiologie, Paris, T. XXX : 155-161.
3. GUNTHER, W. C. 1958. Effect of abnormal incubating temperature on chick behavior. Proc. Ind. Acad. Sci. **66** : 363-366.
4. HARRISON, JOHN R. 1957. Morphogenesis of chick embryo in vitro after exposure to lowered temperatures in ovo. Physiol. Zool. 30(3) : 187-197.
5. HARRISON, JOHN R., and IRVING KLEIN. 1954. Effect of lowered incubation temperature on the growth and differentiation of the chick embryo. Biol. Bull. **106(1)** : 48-59.
6. MORENG, ROBERT E., and REECE L. BRYANT. 1956. The resistance of the chick embryo to low temperature exposure. Poultry Sci. **35** : 753-757.
7. TAYLOR, LEWIS W. 1949. Fertility and hatchability of chicken and turkey eggs. John Wiley & Sons, Inc., New York.

INSTRUCTIONS FOR CONTRIBUTORS

Eligibility

Papers

Indiana Academy of Science members in good standing are eligible to submit papers for publication in the Proceedings. When a paper is signed by two or several authors, all must be members in good standing. Preferably, eligibility should be established before submitting the paper, as such papers are given priority. In any case all authors must be certified by the Treasurer for payment of dues and old reprint bills at the time of the deadline (see below). Papers reaching the editor after the deadline are ineligible. All papers must be accompanied by an abstract in the form specified below, marked "for the editor."

Abstracts

If the Divisional Chairman puts a paper on his program for the Fall Meeting, the abstract will be printed in the Proceedings regardless of the author's membership status, unless the full paper is published.

Time and Procedure for Submitting Abstracts: One typed **original** of each abstract, marked "for the editor," may be submitted to the Divisional Chairman before the meeting or the author may mail it direct to the editor. This should be ready for publication with a minimum of editing, i.e., in the standard abstract form (see a Proceedings abstract) and double spaced; it should not include directions to the chairman regarding time, lantern, etc. The latter information may be added to a copy marked "for the Divisional Chairman" and sent to him. The editor cannot accept carbon copies of abstracts or papers. The length of an abstract should not exceed 200 words. Items A, B, C, E, F, and O apply generally to abstracts as well as papers.

Deadline at Editorial Office

Whether sent *via* the Divisional Chairman as prescribed, or directly, all material for the Proceedings must reach the editor within 20 days following the Fall Meeting.

Preparation of Manuscripts

A. **Refer to current copy of the Proceedings for the accepted style of abstracts and papers, and follow this, especially in literature citations, headings, and footnotes.**

B. Type on 11 x 8½ inch bond paper with a new ribbon, leaving ample margins. **Double-space everything,** including title, author's name and institutions, footnotes, quotations, legends and literature list. The original will become the printer's copy; if it must be retyped it will be sent back to the author for this.

C. Footnotes should be kept to an absolute minimum. Necessary footnotes should be numbered consecutively throughout; asterisks are not used. Acknowledgements may be placed only in the introduction or in a footnote. If your abstract must cite literature, use a footnote.

D. LITERATURE CITATIONS in a paper should not occur in footnotes, but in an **alphabetized** list at the end of the paper, **headed "Literature Cited."** The highly abbreviated form used by chemists has **not** been adopted for the Proceedings. Follow this model:

7. Doe, J. B., and R. C. Roe. 1949. New light from old radioactive carbon. Jour. Am. Biological Soc. 34: 273-305.

E. Only initial letters of the words in titles, headings, and table headings should be capitalized.

F. Do not underline anything except scientific names, in headings or elsewhere.

G. All literature listed, and all tables and illustrations should be **referred to** in the text.

H. Tables, which are very expensive to print, should be reduced to a minimum. Avoid small tables scattered through the text. Each table should be typed on a separate letter-size sheet.

I. New authors, especially, are reminded that a scientific paper should summarize the work, not recapitulate it. It must be very much more concise than a university thesis, avoiding all unnecessary material, especially long tables and lists of little interest except to the author.

J. Major professors are urged to **review** all papers by their graduate students, for both form and content, before they are sent in for publication. Of those based upon university theses, manuscripts carrying a pencilled O. K. and signature by the professor will be given preference over those without such indication of review.

K. Photographs should be printed on glossy paper, and have good contrast. It is best to mount them trimmed to fit tightly together at the edges, in groups on stiff cardboard with rubber cement. Proportion the group for a full page of the Proceedings, or use the full width of the page (4⅛") and any part of the page's height. Do not mix line drawings and photographs in the same group. Legends should be on a separate letter-size sheet, numbered to correspond.

L. The originals for line drawings need be no more than twice the diameter desired for the printed figure. The lettering should be very carefully done, and of suitable size to allow for the necessary reduction. Do not submit printed maps when the necessary reduction will efface the narrower lines or render some of the lettering hardly legible; such maps should be redrawn and lettered in adequate size letters, omitting unnecessary details. It is suggested that the total of illustrations and tables not exceed 20 percent of the length of the whole paper.

M. The summary should be complete and clear in itself, and not over 4 percent of the length of the paper. For very short papers no summary is necessary.

N. Reprints of papers are paid for by authors, at cost. They are ordered at the time the author returns the corrected galley proof to the editor. Abstracts are not reprinted.

O. The editor needs, at the time he mails out galleys in March, **current addresses** for all coauthors of all abstracts and papers. Many former graduate students lose the opportunity to order reprints when mail addressed to them is returned for lack of forwarding addresses. It is suggested that the student's permanent home address be written on the reverse side of that abstract copy marked "for the editor."

Selection of Papers

Every year a few more papers are submitted than can be published with the available funds. Therefore, not all papers received can be included in the Proceedings. Manuscripts prepared concisely, in the style recommended above, will receive first consideration. Authors should not expect to publish very long papers in the Proceedings. Among papers of primarily regional interest, e.g., in certain aspects of botany, zoology, geology, geography, and anthropology, those dealing with Indiana material will be accorded preference.

The selection of papers for the Proceedings is the responsibility of the Editorial Committee.

INDEX

Academy, The Indiana, from horse and buggy to jet, 194.
Acid-catalyzed decarbonylation of 2,4,6-trimethoxybenzaldehyde.
  An anomalous oxidation reaction, 119.
  An accompanying condensation reaction, 99.
Adams, J. R., 205.
Adams, N. E., memorial, 31.
Aedes thibaulti Dyar and Knab, occurrence of, in Indiana, 137.
Anderson, C. E., 61.
Angel site, the identification of a sample of unmodified faunal remains from the, 46.
Antibiotic substances from *Ranunculaceae,* 83.
Anthropology division, 46.
Apple scab pathogen, studies on the biochemical response of *Malus atrosanguinea* to the, 53.
Apple virus diseases in Indiana, further observations on, 54.

Bacillus thuringiensis for insect control, 137.
Bacteriology division, 48.
Baker, P., 260.
Baker, W., 262.
Baldinger, L. H., 6, 19.
Barber, S. A., 6, 227, 228.
Barton, T. F., 170.
Barton II, J., 260.
Bats
  Breeding colonies of four species in Indiana, 262.
  A method of tagging with radioactive gold-198, in homing experiments, 267.
  Notes on homing of two species, *Myotis lucifugus* and *Eptesicus fuscus,* 270.
Baumgardner, M. F., 216, 248.
Beetles, distribution of caverniculous, in Indiana, 260.
Bertrand, A. R., 216.
Beta spectra, shape of, of once forbidden transitions in the decay of Ga^{72}, La^{140}, Eu^{152}, Eu^{154}, and Sb^{124}, 205.
Biographical sketches of Indiana scientists not listed elsewhere I, 182.
Black, H., 20, 203.
Bloom, W. W., 6, 7, 11, 12, 18, 19, 20.
Botanical division, 51.
Bowen, R., 119.
Boyer, M. C., 165.
Brandt, W., 20.
Bretscher, M. M., 206.
Brooks, A. E., 73.
Buck, R., 200.
Burkett, H. B., 6, 119.

Cabbage worms, control of, 137.
Campaigne, E., 99.
Carbostyrils, reduction studies of various substituted, 115.
Carlson, K. H., 6, 20.
Cassaday, J., 99.
Ceratium hirundinella (O. F. Müller) Shrank, forms of, in lakes and ponds of Indiana, 213.
Cetyltrimethylammonium bromide, action of, on the bacterial cell, 48.
Chandler, L., 138.
Chemical terms derived from Greek, 98.
Chemistry division, 98.
Chick behavior, some effects of high and low incubating temperatures on, 285.
Cho, C. S., 99.
Chromatography in taxonomy, the role of paper, 207.
Churchwell, E., 267, 270.
Cieciura, S. J., 48.
Clark, F. B., 234.
Clauser, E. H. M., memorial, 32.
Clements, J. N., 51.
Clewell, A. F., 207.
Coats, N., 7, 16.
Cobb, G. W., 54.
Colburn, D. C., 6.
Cole, C., 139.
Computer, an analog, teaching physics with, 204.
Confer, J., 262.
Cook, D. J., 6, 7, 9, 13, 115.
Cope, J. B., 262, 267, 270.
Corn leaf aphid, *Rhopalosiphum maidis* (Fitch), sorghum resistance to, 137.
Corn root, the response of, to high nutrient concentrations within a single root culture cell, 254.
Crises, past and present, 200.
Cummins, G. B., 96.
Cyclic esters of organic acids, I, 106.

Daily, F. K., 6, 20, 182, 194.
Daily, W. A., 6, 7, 16, 20, 207, 213.
Davis, R. E., 100, 106.
Day, H. G., 19.
Deay, H. D., 137.

Decker, R. D., 66.
DeLanney, L. E., 7, 20, 261.
Dental caries, change of incidence of, with dieting changes in prehistoric Indian populations, 47.
Dilling, R., 203.
Dimethyl sulfoxide complexes, a preliminary study of differential thermal analysis, conductance and cryoscopic behavior of, 123.
Diptera populations in the Whitewater Valley, 142.
Direct interactions in (α, p) processes, 203.
Disulfides, ultraviolet absorption spectra of unsymmetrical, 99.
Doan, M., memorial, 33.
Dobson, R. C., 52.

Eberly, W., 7, 8, 9, 16, 51.
Ecology, Wabash floodplain, 54.
Edington, W. E., 7, 31, 182.
Edwards, P. D., 7, 14.
Ek, C. M., memorial, 34.
Electromagnetic field with a finite plasma, the interaction of an, 204.
Entomology division, 137.
Epifagus virginiana, a preliminary morphological study of, 73.
Evans, S. D., 227.
Evaporation and solar radiation in Indiana, 216.
Everly, R. T., 137.

Face fly (*Musca autumnalis* DeGeer) in Indiana, 1960, field observations of, 152.
Farringer, L. D., 204.
Ferguson, L., 48.
Flanders, H., 201.
Floods, geomorphology and, 165.
Flores, J. G., 217.
Ford, B. T., 137.
Frazier, R., 216.

Gametophytes, fern, 56.
Gamma ray spectroscopy, a project in, 203.
Garner, H. R., 49.
Genus *Solanum* (*S. integrifolium* Poir X *S. melongena* L.), a wide species cross in the, 207.
Geology and geography division, 154.
Geomorphology and floods, 165.
Gill-lessness in newts and axolotls, experimental production of, 261.
Girton, R. E., 52.
Glycine max, the organization of the root apex of, 61.
Gohlke, A. F., 216, 248.
Gosselink, J. G., 203.
Gould, G. E., 137.
Green, Jr., R. J., 53, 87.
Grollig, F. X., 46.
Ground squirrel, distribution of the 13-lined, in Indiana, 275.
Guard, A. T., 6, 7, 9, 51.
Guatemala, C. A., accelerated acculturation of Mayan Indians in, 46.
Guernsey, Lee, 158.
Gunther, W. C., 285.
Guthrie, N., 98.

Hadar, B. R., 48.
Hagen, C. W., Jr., 207.
Hall, M. T., 201.
Hallerberg, A. E., 201.
Hartsock, J. G., 137.
Heiser, Jr., C. B., 209.
Helianthus deserticolus, a new annual sunflower, from the Southwestern United States, 209.
Hendrix, J. R., 260.
Hennen, J., 20.
Herrala, E. A., 47.
Hiratsuka, Y., 96.
History of science division, 182.
Homograft reactions in axolotls, preliminary observations on, and their possible genetic implications, 261.
Hook, J. C., 6, 154.
Hopp, W. B., 260.
Hoshaw, R. W., 52.
Howe, R. H. L., 155.
Human resources, progress made in increasing Indiana's, 189.

Index, 296.
Instructions for contributors, 293.
Insect orders from 3 types of vegetational cover on Miami, Bethel and Brookston soils in eastern Indiana, quantitative comparison of, 139.
Insects and other arthropods of economic importance in Indiana in 1960, 145.

Jenkins, M. B., 49.
Jewell, M. E., 48.
Johnson, E. R., 261.
Johnson, W. H., 13.
Johnson, W. P., 205.
Jones, R. K., 285.
Junior academy—clubs, council members, exhibits, minutes, officers and program, 23.
Just, T. K., memorial, 35.

Kang, B. T., 254.
Keim, W., 123.
Kelley, A. G., 56.
Keller, J. H., 20, 46.
Kirkpatrick, R. D., 275.
Klinge, P., 8, 9.
Konetzka, W. A., 48.

Koontz, K., 267, 270.
Krekeler, C. H., 6, 260.

Land color theory, an artist's response to, 205.
Langer, L. M., 205.
Laubengayer, R. A., 6, 7, 8, 14.
Lavy, T., 238.
Lefler, R. L., 7, 18.
Lespedeza, taxonomic problems in, 207.
Light traps protect tobacco from hornworms, 137.

Maciejowska, Z., 52.
Maize mutants, the use of, to characterize normal development, 51.
Mallett, G., 20, 48.
Manske, P., 285.
Marie Bernard, Sister, O. S. F., 83.
Markle, C. A., 7, 14.
Marsh, T. E., 142.
Mathematicians, comment on the liaison between high school and college, 201.
Mathematics
  and the younger generation, 200.
  course, a new, at DePauw, 202.
  division, 200.
  the state of, in the state of California, 201.
Matthew, D. L., 152.
Maxwell's demon theory, an extension of, 203.
McCoy, Scott, 7, 20.
McGregor, M., 20, 154.
Measles virus, the influence of serum on the cytoplasmic effect of, 48.
Meikle, G. S., memorial, 37.
Memorials
  Adams, W. E., 31.
  Clauser, E. H. M., 32.
  Doan, M., 33.
  Ek, C. M., 34.
  Just, T. K., 35.
  Meikle, G. S., 37.
  White, J., 38.
Mentha spp. in commercial mint plants, stolon decay of, 53.
Metzger, M. J., 83.
Meyer, W. W., 99.
Michaud, H. H., 7, 17.
Micromagnetic waves, 154.
Mink, G., 54.
Molybdenum status of some Indiana soils, 238.
Monroe reservoir, a multiple use project, the, 170.
Morgan, W. P., 7.
Morphology of the spermogonium of *Gymnoconia peckiana,* a rust fungus, 96.
Morris, C. S., 6, 203.
Moura, R. A., 48.
Mumford, R. E., 275.
Murray, H. L., 49.

Nainan, T. D., 204.
Nakatsukasa, W., 48.
Natrix sipedon, preliminary studies on the growth rate of, 260.
Neal, Jr., R. R., 261.
Necrology, 31.
Nelson, O. E., 51.
Neumann, G. K., 46.
Neumann, H. W., 46.
Neutron physics, student experiments in, 206.
New members, 21.
Nichols, L. D., 132.
Niswander, R. E., 6, 137, 138.
Nitrogen for corn, evaluation of three sources of, 217.
Noveroske, R. L., 53.
Nuclear energy states, half-lives of some, in the mμ-Sec region, 204.
Nuclear fractionation schemes, a critique of, 260.

Oak wilt, studies of the control of, in Indiana, 87.
Ohlrogge, A. J., 254.
One dimensional atomic potential functions, some, 132.
Osmun, J. V., 145.
Oxygen production in some lakes in northern Indiana, 51.

Physics division, 203.
Plant structure, recent approaches to, 41.
Plant taxonomy division, 207.
Polley, J. C., 8, 17.
Postlethwait, S. N., 6, 51, 56, 61, 66.
Presidential address, 41.
Prickett, P. S., 49.
Primary mammalian cells in suspension culture, growth behavior of, 48.
Palmer, T. P., 200.
Peroxidase distribution in geotropically stimulated candles of *Pinus strobus* L., 79.
Petty, R. O., 54.
Petuely's medium, application of, to the selection and differentiation of *Lactobacillus bifidus,* 49.
Physics teaching and research in Indonesia, the status of, 203.
Pierce, R. N., 115.
Plethodon, a postfemoral spot in, 278.
Ploughe, W. D., 203.
Pot culture—an aid to site evaluation, 234.
Potato nutrition in southwestern Indiana, 243.
Predation, differential, in *Osmia cordata* Robt. — *O. lignaria* Say nesting associations (Hymenoptera, Megachilidae), 138.
Proton magnetic resonance spectra of amino acids in D_2O solution, 204.

Proton polarization measurements, 205.

Range limits, plant, in Wabash valley, 54.
Respiration of maize and rice root tips, effects of oxygen and inhibitors, 52.
Reynolds, A. E., 278.
Rice, W. J., 7.
Ricketts, J. A., 99, 132.
Root apex of *Glycine max*, the organization of, 61.
Rose Polytechnic Institute, the mathematics program at, 200.

Saguaro cactus, problems related to the giant, 52.
Salter, L. W., 203.
Sands, G., 238.
Satellite telescopes and meteorites, 205.
Schaal, L. A., 216.
Schafer, J. F., 91.
Schiff bases of p-aminoazobenzene, the spectra of some, 99.
Schreiber, L. R., 87.
Scolecotrichum graminis Fckl., the biology of, causing leafstreak of orchard grass, 54.
Selenium chains, stepwise construction of surfur and, 100.
Settlement changes caused by strip coal mining in Indiana, 158.
Shanks, M. E., 20.
Shay, J. R., 54.
Shea, G. J., 154.
Shirer, D. L., 204.
Siverley, R. E., 20, 137.
Smith, D. R., 205.
Soil analysis techniques evaluation, 248.
Soil depth and soil volume, effect of, upon corn yield in a greenhouse experiment, 227.
Soil fungi, the isolation and identification of, and their relation to root rot of apple, 52.
Soil science division, 216.
Soil test correlation, 216.
Soils, molybdenum status in Indiana, 238.
Solar radiation and evaporation in Indiana, 216.
Spermogonium, morphology of, in *Gymnoconia*, 96.
Stanley, P. E., 205.
Starcs, H., 20, 207.
Sterling, D. K., 54.
Stivers, R. K., 217.
Strip coal mining in Indiana, settlement changes caused by, 158.
Subsoiling and subsoil fertilization, predicting the response of corn to, 216.
Sulfur and selenium chains, stepwise construction of, 100.
Syringe driver, a programmable multiple, for use in metabolic studies with filamentous fungi, 49.

Telial formation, variability of, of *Puccinia coronata*, 91.
Thomas, R. J., 202.
Tomato, an anatomical and morphological study of a sidebranchless, 51.
Trifoliate leaf of *Glycine max*, the maturation of the, 66.
Tsurugi, J., 99.
Tuite, J., 54.
Tukey, R., 216.
Types, the physical, occurring in the historic Illinois (Peoria), Miami, Sauk, and Shawnee tribes, 46.

Van Asdall, W., 54.
Vegetation, Wabash valley, 54.
Visher, S., 189.

Wadia, M. S., 6, 46.
Wallace, F. N., 7.
Ward, G. L., 139, 142.
Water resources, discovery and evaluation of, by aerial photographic methods, 155.
Weaver, E. E., 123.
Weinberg, E., 6.
Welch, W. H., 8.
Westing, A. H., 79.
White, J., memorial, 38.
White, J. Y., 48.
Wiersma, Dan, 217.
Wilcox, G. E., 243.
Williams, E. B., 52, 53.
Wolfe, J. G., 204.
Woodham, G., 281.

Yates, W., 207.
Young, F. N., 20.
Yuncker, T. G., 7, 16, 182.

Zassenhaus, H. J., 200.
Zimmer, D. E., 91.
Zoology division, 260.
Zygmunt, W. A., 6, 48.